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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1906. [January.

THE MINERAL PRODUCTION OF INDIA DURING 1904. BY T. H. HOLLAND, F.R.S., *Director, Geological Survey of India.*

CONTENTS.

I.—INTRODUCTION.

IN addition to the Quinquennial Reviews of Mineral Production, of which the first issue formed Part 1 of the last volume of these *Records*, the Government of India have ordered the publication of a brief statement each year of the quantity and value of each of the important minerals raised in India. This statement will

replace that issued hitherto in pamphlet form by the Director-General of Statistics.

The system of tabulating the returns agrees with that adopted for the Review of Mineral Production: the minerals are divided into—(I) those for which approximately trustworthy returns are available, and (II) those for which the figures are obviously incomplete. As improvements are being gradually made in the system of collecting statistics, the first group is increased at the expense of the second, until the residue of uncertain estimates will become an unimportant fraction of the total. Two more minerals—chromite and diamonds—are added this year to the list forming Group I, though the values for both are still small.

Total Value of Production.

The summary of total values forming table 1 shows that the output of the minerals of Group I during 1904 exceeded in value that for 1903 by £347,236, an increase of nearly 7 per cent., which is slightly below the average rate of advance recorded for the previous five years.[1]

[1] *Cf.* Review of Mineral Production, *Rec. G. S. I.*, XXXII, 1905, p. 3.

TABLE I.—*Total Value of Minerals for which Returns of Production are available for the years 1903 and 1904.*

—	1903.	1904.
	£	£
Gold	2,303,144	2,366,079
Coal (*a*)	1,299,716	1,398,826
Petroleum (*a*)	354,365	473,971
Salt (*a*)	336,147	437,530
Saltpetre (*b*)	290,196	266,349
Manganese-ore (*b*)	151,530	129,632
Mica (*b*)	86,296	97,932
Rubies	88,819	90,612
Jadestone (*b*)	55,435	50,726
Graphite (*a*)	16,970	16,726
Iron-ore (*a*)	14,963	12,617
Tin-ore (*a*)	9,153	8,353
Chromite (*a*)	327	4,137
Diamonds	2,579	2,636
Magnesite (*a*)	550	876
Amber	414	838
TOTAL	5,010,604	**5,357,840**

(*a*) Spot prices. (*b*) Export values.

Deficiencies in the Table of Total Values.

As explained in the Review for 1898—1903, these values are not strictly comparable to those returned for other countries. The instance of manganese-ore was quoted before as an illustration of the low value of an ore in this country where metallurgical industries are in such a rudimentary condition. The mineral chromite, now being regularly mined in Baluchistan, offers a new instance of the loss incurred by the export of raw metalliferous ores. The value returned for chromite is 23*s*. per ton, whereas its price at an American or European port would be about £3-15*s*.

In another way the table understates the actual value of minerals produced in India by the omission of products for which no returns, or obviously imperfect ones, are obtainable. Some of these are very serious items, and amount in the case of those for which partial returns have been obtained to £110,981. These are referred to in the notes with regard to the minerals of Group II (*infra*, p. 19, *et seq*.). The table, however, fairly expresses the *progress* which has been made, for where greater precision has been introduced in the returns for 1904 care has been taken to revise those for 1903 in the same way: both years are thus reduced to the same standard for comparison, and though table No. 1 does not show the total for either year, the two columns may be safely accepted as forming a true measure of the progress made in the interval.

Licenses issued.

Besides the increase in production there has been a more marked development of interest in the mineral industries shown by an increase of 50 per cent. in the prospecting and mining licenses and leases taken up (*vide infra*, table 26).



II.—MINERALS OF GROUP I.

Chromite.	Graphite.	Manganese-ore.	Salt.
Coal.	Iron-ore.	Mica.	Saltpetre.
Diamonds.	Jadeite.	Petroleum.	Tin.
Gold.	Magnesite.	Rubies.	

Chromite.

THE exploitation of the chromite deposits in Baluchistan, which were discovered by Mr. E. Vredenburg of the Geological Survey in 1901, did not commence until 1903, when 284 tons were produced. During the past year work extended in both prospecting and mining, the quantity of ore raised amounting to 3,596 tons valued at £4,137, or 23*s*. a ton.

Of the total, 3,466 tons were obtained from the Khánozai deposits in the Quetta-Pishin district, and 130 tons from Hindubágh in the Zhob district. The ore is raised entirely for export to Europe; but the spread of the chrome-tanning industry now being organized in Madras should create a local demand for large quantities of chromic acid.

Coal.

The production of coal has again exceeded previous records, having amounted to 8,216,706 tons in 1904, against 7,438,386 tons in 1903, an increase of 10·5 per cent. To this increase of the total both the Tertiary and the Gondwana coalfields have contributed, as shown in table 2.

TABLE 2.—*Origin of Indian Coal raised in 1903 and 1904.*

—	1903.		1904.	
	Statute Tons.	*Metric Tons.*	**Statute Tons.**	*Metric Tons.*
From Gondwana Coalfields .	7,076,376	*7,189,933*	**7,808,027**	*7,933,325*
From Tertiary Coalfields .	362,010	*367,818*	**408,679**	*415,236*
TOTAL .	**7,438,386**	*7,557,751*	**8,216,706**	*8,348,561*

TABLE 3.—*Provincial production of Coal for 1904 compared with that for 1903.*

PROVINCES.	1903.		1904.	
	Quantity.	*Value.*	**Quantity.**	*Value.*
	Statute Tons.	£	**Statute Tons.**	£
Assam	239,328	*75,791*	**266,765**	*84,592*
Baluchistan	46,909	*30,191*	**49,867**	*27,308*
Bengal	6,361,212	*951,803*	**7,063,680**	*1,015,147*
Burma	9,306	*2,482*	**1,105**	*294*
Central India	193,277	*49,775*	**185,774**	*47,060*
Central Provinces . .	159,154	*48,019*	**139,027**	*43,664*
Hyderabad	362,733	*117,888*	**419,546**	*150,345*
Kashmir	999	...	**270**	...
Punjab	43,704	*18,837*	**45,594**	*22,144*
Rajputana (Bikaner) . .	21,764	*4,930*	**45,078**	*8,272*
TOTAL .	**7,438,386**	*1,299,716*	**8,216,706**	*1,398,826*

The coal production reported for the Kashmir State refers to prospecting operations only, carried on in the Jammu hills.[1] Of the remaining provincial areas an increase of production is recorded for all except Burma, Central India and the Central Provinces. The decline in the output of coal in Burma is due to the closing in February 1904 of the Letkopin mines in the Shwebo district. The production reported for Central India, though less than that for 1903, is in reality an increase on the previous average, the greater production in 1903 being due to exceptional activity at the time when the Singareni mines were feeling the effects of the serious accident in 1903, and were unable, consequently, to meet the usual demands of the Great Indian Peninsula Railway. As explained in the Review of Mineral

[1] *Cf.* R. R. Simpson, *Mem. Geol. Surv. Ind.*, Vol. XXXII, Part 4, 1904.

Production (Vol. XXXII, *p. 33*), works in the Warora colliery are being restricted in favour of developments at Bellarpur, whilst the other colliery in the Central Provinces, Mohpâni, shows a decreased output in consequence of the changes about to be introduced on the transfer of the property from the Nerbudda Coal and Iron Company to the Great Indian Peninsula Railway.

TABLE 4.—*Output of Gondwana Coalfields during 1903 and 1904.*

COALFIELDS.	1903.		1904.	
	Statute Tons.	*Per cent. of Indian Total.*	**Statute Tons.**	Per cent. of Indian Total.
Bengal—				
Daltonganj . . .	*33,557*	*·45*	**50,517**	·61
Giridih . . .	*766,871*	*10·31*	**773,128**	9·41
Jherria . . .	*2,493,729*	*33·52*	**2,889,504**	35·17
Rajmahal . . .	*335*	...	**274**	...
Raniganj . . .	*3,066,720*	*41·22*	**3,350,257**	40·77
Central India—				
Umaria . . .	*193,277*	*2·60*	**185,774**	2·26
Central Provinces—				
Bellarpur . . .	...	...	**90**	...
Mohpani . . .	*31,443*	*·42*	**26,618**	·32
Warora . . .	*127,623*	*1·72*	**112,319**	1·37
Hyderabad—				
Singareni . . .	*362,733*	*4·89*	**419,546**	5·11
TOTAL of Gondwana Coal .	**7,076,288(*a*)**	*95·13*	**7,808,027**	95·02

(*a*) Includes 58 tons raised during prospecting operations in the Pench Valley, Central Provinces.

TABLE 5.—*Production of Tertiary Coal in 1903 and 1904.*

COALFIELDS.	1903.		1904.	
	Statute Tons.	*Per cent. of Indian Total.*	**Statute Tons.**	**Per cent. of Indian Total.**
Assam—				
Makum	*239,328*	*3·23*	**266,265**	3·25 (Makum and Smaller fields)
Smaller fields	...	...	**500**	
Baluchistan—				
Khost	*36,444*	*·49*	**38,574**	·47
Sor Range, Mach, etc.	*10,465*	*·14*	**11,293**	·14
Burma—				
Shwebo	*9,306*	*·12*	**1,105**	·02 (Shwebo and Ladda)
Kashmir—				
Ladda	*999*	*·01*	**270**	
Punjab—				
Salt Range mines	*43,704*	*·59*	**45,258**	·55 (Salt Range mines and Attock district)
Attock district	...	...	**336**	
Rajputana—				
Bikaner	*21,764*	*·29*	**45,078**	·55
TOTAL of Tertiary Coal	**362,010**	*4·87*	**408,679**	**4·98**

Exports.

The exports of Indian coal, though still small compared with the production and internal consumption, exceeded previous records in 1904, the amount being 602,810 tons, compared with 441,948 tons in 1903 (table 6).

TABLE 6.—*Exports of Indian Coal during 1903 and 1904.*

Exported to	1903.	1904.
	Tons.	Tons.
Aden	*31,210*	31,620
Africa, East	*30,645*	21,263
Ceylon	*252,912*	360,697
Straits Settlements	*111,520*	144,545
Sumatra	*10,993*	32,810
Other countries	*4,668*	11,875
TOTAL	*441,948*	**602,810**

Consumption of Coal on the Railways.

The Indian coal consumed on the railways in the country in 1904 amounted to 2,447.341 tons, against 2,203,889 tons in 1903. The railways thus took 29·8 per cent. of the production, against an average of 29·7 per cent. for the preceding six years.[1] At the same time the consumption of foreign coal was reduced slightly from 17,696 tons in 1903 to 17,432 tons in 1904.

Labour.

The average daily attendance at Indian coal mines in 1904 amounted to 92,740, and the average output per person employed was 88·6 tons, as compared with 84 tons in 1903. Details of accidents and their consequences at mines worked under the Mines Act of 1901 will be found in the Report of the Chief Inspector of Mines.

Diamonds.

Diamond-mining persists, without signs of increased development, in the Vindhyan belt, stretching through the Central Indian States

[1] Review of Min. Production. *Rec. G. S. I.*, XXXII, page 21.

of Panna, Charkhari, Ajaigarh and Bijáwar. Returns for these four States for 1903 and 1904 show the following totals :—

YEAR.	Quantity.	Value.
	Carats.	£
1903	210·74	2,579
1904	286·48	2,636

These figures practically represent the total output for India, although prospecting operations are in progress elsewhere.

Gold.

In addition to the continued success of the mines on the Kolar gold-field, increasing returns are being shown for the Hutti Mine in the Lingsugur district of the Nizam's Dominions. Developments are proceeding in the Dharwar area with encouraging results, whilst considerable interest has been developed in gold-dredging in Burma on account of the good results reported for the Irrawaddi river in the Myitkyina district. Concessions for dredging have been granted also in the Chindwin river, and for alluvial mining in the Northern Shan States. The figures given in table 7 show that Mysore and Hyderabad are the only areas so far showing returns of serious value.

TABLE 7.—*Quantity and Value of Gold produced in India during 1903 and 1904.*

PROVINCES.	1903.		1904.	
	Quantity.	*Value.*	Quantity.	*Value.*
	Ounces.	£	Ounces.	£
Burma	1,095	*3,988*	216	*810(a)*
Hyderabad	3,809	*14,505*	10,559	*40,624*
Mysore	598,709	*2,283,999*	607,578	*2,323,183*
Punjab	150	*562*	370	*1,379*
United Provinces . . .	24	90	23	*83*
TOTAL .	603,787	*2,303,144*	618,746	*2,366,079*

(*a*) Estimated at £3 15*s*. per ounce.

The growth of the Hutti Mine since its start in 1903 is indicated by the monthly returns for production shown in table 8.

TABLE 8.—*Monthly production of Bar Gold at the Hutti (Nizam's) Mines for 1903 and 1904.*

MONTHS.	1903.	1904.
January	*No production.*	652·8
February		651·8
March	*107·7*	720·0
April	*302·4*	518·5
May	*343·7*	797·4
June	*388·6*	806·2
July	*417·9*	807·0
August	*431·4*	904·4
September	*442·3*	1,140·3
October	*444·2*	1,207·6
November	*457·7*	1,222·0
December	*473·5*	1,130·6
TOTAL .	*3,809·4*	**10,558·6**

Value of Gold :—

1903 . . . . . . £ *14,505.*
1904 . . . . . . £ **40,624.**

Native Gold-washing.

Gold-washing in the rivers is practised in many parts of India by a limited number of people contented with a small income. In the Mánbhum district as many as 230 people were reported to be engaged in gold-washing in 1904, and for Singhbhum the reports show a total of 413 gold-washers. In the United Provinces the industry is reported to employ about 100 workers in the Nagina tahsil of Bijnor district, and smaller numbers are

returned for Garhwál and Naini Tál. Gold-washing flourishes, too, in some of the Punjab rivers, especially in the Indus.

Reports from Báltistán show that the washing of ancient gravel deposits has been carried on on quite an extensive scale, actual mining operations having been undertaken to excavate the gold-bearing bands in the old river terraces in the Dras valley.

Graphite.

The production of crude graphite in Travancore during 1904 amounted to 3,256 tons, against 3,394 tons in 1903. The most active prospecting operations undertaken outside Travancore have been carried on in the Bhadráchalam taluk of the Godávari district. The work has not, however, progressed beyond the prospecting stage. The total value of graphite produced in 1904 is estimated at the pit-mouth at £16,726.

Iron-ore.

The iron-ore raised in Bengal mainly for the Barakar Iron and Steel Works amounted to 88 per cent. of the reported total for India. The returns for the other areas are estimated with varying degrees of accuracy according to the number of native furnaces at work, but the possible error, being limited to the smaller fraction of 12 per cent. does not seriously affect the total. The limit of error is also reduced by the fact that in the Central Provinces, where the native iron-smelting industry persists with signs of vigour, the most elaborate care is taken to determine the state of the industry in each district and Zemindari.

The value reported for Bengal works out to an average of Rs. 2-4 (3*s*.) per ton, but for the rest of India, the ore being of higher quality and raised at places often distant from the railways as well as the ports, a higher average value is reported. For the Central Provinces the average value is Rs. 4-7 per ton, and for Madras Rs. 3-8. The error will not be great if we adopt Rs. 4 as the average value for all the iron-ore raised outside Bengal. The full returns for 1904 thus show a total quantity of 71,608 tons of ore, valued at £12,617.

In the Central Provinces, 441 small direct-process furnaces were at work, 154 of these being in the Sambalpur district, and 98 in Jubbulpore. Prospecting operations in the Raipur district near Dhullee, 38 miles south of the Bengal Nagpur main line, have proved

the existence of an enormous body of hematite in which the percentage of iron, determined from the average of a number of boring cores as well as surface samples, is just 68.

Rich ore-bodies have also been determined in the Mayurbhanj State, Orissa, and, as the result of the work conducted by Messrs. C. P. Perin and C. M. Weld on behalf of Messrs. J. N. Tata & Sons, it has been decided to erect iron and steel works at Sini on the Bengal-Nagpur Railway with the intention of using the Mayurbhanj ore in conjunction with fuel from the Jherria coal field.

Jadeite.

Jadeite-mining is confined to an unadministered part of the Myitkyina district in Burma, and the returns for production are obviously understated, the reported quantity being only about two-thirds of that exported. The jadestone exported through Rangoon in 1904 amounted to 2,869 cwts., valued at £43,946, against 2,192 cwts. valued at £50,582 in 1903. Besides that sent out by sea considerable quantities of jadeite are carried overland from Upper Burma into China. During 1904 the quantity sent overland into China amounted to 909 cwts., valued at £6,780.

The returns for jadestone exported during 1903 and 1904 were as follows:—

ROUTE.	1903.		1904.	
	Weight.	*Value.*	Weight.	*Value.*
	Cwts.	£	Cwts.	£
Through Rangoon . . .	2,192	*50,582*	2,869	*43,946*
Overland	446	*4,853*	909	*6,780*
TOTAL .	**2,638**	*55,435*	**3,778**	*50,726*

Magnesite.

The only locality being worked for magnesite is that of the Chalk hills near Salem. The production reported for 1904 was 1,315 tons,

valued at £876, or at the rate of R10 (13*s*. 4*d*.) a ton, which is about half the value of the mineral at an European or American port.

Manganese-ore.

The rapid rise in the production of manganese-ore that marked all previous years received a distinct check last year, the production for 1904 being only 150,297 tons, compared with 171,806 tons in 1903 (table 9). This interruption in the previously continuous rise in output is mainly due to the low market prices which prevailed during the past and the previous year. There was a corresponding drop in the exports from 176,611 tons in 1903 to 154,830 tons in 1904.

TABLE 9.—*Production of Manganese-ore for 1903 and 1904.*

—	1903.		1904.	
	Statute tons.	*Metric tons.*	Statute tons.	*Metric tons.*
Central India—				
Jhabua State	6,800	*6,909*	11,564	*11,749*
Central Provinces—				
Bálaghát district . . .	7,898	*8,024*	10,323	*10,489*
Bhandára „	...	...	8,558	*8,695*
Nágpur „	93,656	*95,159*	66,153	*67,214*
Madras—				
Vizágapatám district . .	63,452	*64,470*	53,699	*54,560*
TOTAL .	**171,806**	*174,562*	**150,297**	*152,707*

Mica.

The returns for mica exported, given in table 10, show that, compared with 1903-04, there was a decrease in weight, but a very distinct

increase in value in 1904-05. The increase is due entirely to greater activity in the Nellore district, where the mining rules have been more strictly enforced during the past year.

TABLE 10.—*Exports of Indian Mica for the years 1903-04 and 1904-05.*

FROM	1903-04.			1904-05.		
	Weight.	Value.	Value per cwt.	Weight.	Value.	Value per cwt.
	Cwt.	£	£	Cwt.	£	£
Bengal . .	18,001	67,801	3·77	13,167	59,187	4·50
Bombay . .	217	374	1·72	74	132	1·78
Madras . .	3,330	18,121	5·44	6,334	38,613	6·10
TOTAL .	21,548	86,296	4·05	19,575	97,932	5·00

Of the two chief competitors in mica-production, the United States in 1904 turned out 5,967 cwts. of sheet mica, valued at £21,892, and scrap mica to the extent of 1,096 short tons, valued at £2,171. In the same year the foreign mica imported into the States was valued at £52,743. The preliminary figures obtained by the Geological Survey of Canada show a mica-production for the Dominion in 1904, valued at £30,434. The value of the mica produced in India is thus much greater than that of the United States and Canada combined.

Petroleum.

There has been very little change in the oil-wells of the Punjab, whilst those of Assam show only a slight increase in production, compared with the remarkable development of the three principal Burma oil-fields. Table 11 shows the provincial returns for the last two years.

TABLE 11.—*Production of Petroleum for 1903 and 1904.*

PROVINCE.	1903.	1904.
	Gallons.	Gallons.
Assam	*2,528,785*	2,585,920
Burma	*85,328,491*	115,903,804
Punjab	*1,793*	1,658
TOTAL, Gallons .	**87,859,069**	**118,491,382**
Total, Metric Tons .	*352,848*	*475,869*

The increase in Burma represents 35·8 per cent. of the output in 1903, the greatest proportionate development having been in the new Singu field on the left bank of the Irrawaddi.

TABLE 12.—*Production of the Burma Oil-fields for 1903 and 1904.*

OIL-FIELD AND DISTRICT.	1903.	1904.
	Gallons.	Gallons.
Akyab	*52,968*	47,082
Kyaukphyu	*71,962*	89,827
Yenangyaung, Magwe	*56,920,662*	73,428,960
Singu, Myingyán	*5,617,381*	23,677,450
Yenangyát, Pakôkku	*22,665,518*	18,660,485
TOTAL, Gallons .	**85,328,491**	**115,903,804**
Total, Metric Tons .	*342,685*	*465,475*

The rapid increase in production has naturally displaced some of the imported foreign oil, of which only 70,590,858 gallons were introduced, against 76,361,579 gallons in 1903. The reduction has

been entirely on Russian oil, for there has been at the same time a marked increase in the importation of oils from the Dutch East Indies (table 13).

TABLE 13.—*Imports of Foreign Kerosene during 1903 and 1904.*

—	1903.	1904.
	Gallons.	Gallons.
Russia	*65,434,324*	42,256,738
United States	*7,588,569*	7,628,275
Borneo	*1,078,719*	6,931,291
Straits Settlements	*1,280,507*	8,985,538
Sumatra	*974,981*	3,566,619
Other countries	*4,479*	1,222,397
TOTAL	*76,361,579*	**70,590,858**

At the same time there has been a considerable increase in the exports of petroleum from 747,834 gallons in 1903 to 3,787,677 gallons in 1904.

Ruby.

The output of rubies, including small quantities of sapphire and spinel, reported by the Ruby Mines Company, Burma, for the year ending February 28th, 1905, amounted to 265,901 carats, valued at £90,612, against 227,213 carats, valued at £88,819 in the corresponding period ending February 29th, 1904. Considerable quantities of rubies are obtained also by native miners, working under license from the Company, but accurate returns are not available.

Salt.

There was a great increase during 1904 in the production of salt, and an increase also in the imports, the two together responding to the increased demand following the reduction of the salt tax. Table 14 shows the provincial contributions to the total production.

TABLE 14.—*Provincial Production of Salt during 1903 and 1904.*

—	1903.	1904.
	Statute Tons.	Statute Tons.
Aden	*71,656*	66,007
Bengal	*63*	88
Bombay	*267,619*	430,409
Burma	*25,921*	20,532
Gwalior State	*489*	374
Madras	*244,923*	356,834
Northern India	*270,068*	282,421
Sind	*13,817*	13,540
TOTAL, Statute Tons .	**894,556**	**1,170,205**
Total, Metric Tons	*908,911*	*1,188,900*

A portion of the salt returned for Northern India is obtained by mining rock-salt in the Punjab and North-West Frontier Province. This is shown in table 15.

TABLE 15.—*Production of Rock-Salt for 1903 and 1904.*

—	1903.	1904.
	Statute Tons.	Statute Tons.
Salt Range, Punjab	*90,736*	107,403
Kohát	*15,598*	16,664
Mandi	*4,554*	4,507
TOTAL, Statute Tons .	**110,888**	**128,574**
Total, Metric Tons	*112,670*	*130,635*

The salt imported in 1904 amounted to 471,096 tons, against 408,941 tons in 1903 and an average of 433,754 tons for the previous six years.

Saltpetre.

The refined saltpetre produced in Northern India during the financial year 1904-05 amounted to 315,558 cwts., against [illegible]98,551 cwts. in 1903-04. The provincial production was as follows:—

—	1903-1904.	1904-05.
	Cwts.	Cwts.
Punjab and North-West Frontier Province .	...	61,306
United Provinces	...	89,550
Behar	...	164,702
TOTAL .	308,551	315,558

In these provinces there were 399 registered refineries at work in 1904-05, 281 of them being in Behar.

The saltpetre exported during 1904 amounted to 390,970 cwts. against 412,593 cwts. in 1903.

Tin.

Tin-washing on a comparatively small scale continues in South Burma and in the Karenni, but concessions have been taken in the former area with the intention of washing the stanniferous gravel on a large scale. The output reported for 1904 was smaller than for 1903, the total for Tavoy and Mergui districts being 1,388 cwts., valued at £8,242, and that for the Bawlake State, Karenni, being returned as 26 cwts., valued on the spot at £111.

III.—MINERALS OF GROUP II.

THE following notes refer to minerals reserved to Group II on account of the imperfect returns received regarding their production.

Alum. The Punjab Government reports the production in the Mianwáli district of 129 tons of alum, valued at £700.

Amber. The amber raised in the Myitkyina district of Burma in 1904 is estimated to amount to 86 cwts., valued at £838. This amount has been included in the table of values on page 2, but it is probable that it does not represent the total production.

Asbestos. A small quantity of asbestos was raised in the Ajmer-Merwára district, amounting to about a ton of small value, and obtained during prospecting operations.

Borax. The borax produced in the Puga valley of Ladákh, Kashmir, is returned as 810 cwts., valued at £168.

Building stone. The production of building stone has been determined with elaborate care by the Burma Government, but for the other provinces only partial returns are available. These partial returns amount in value to £53,153, exclusive of clay used for bricks and tiles, limestone used in various ways, including the flux used in the Barákar iron-works, gypsum, marble and slate. The principal item of interest included under this head is the well-known Vindhyan sandstone quarried at Chunár and Mirzapur, of which 76,484 tons, valued at £6,987, were quarried in 1904.

Clay. There is a regular, but small, industry in the production of *Multan-i-mitti*, a form of fullers' earth occurring in the States of Bikaner and Jaisalmer. The amount raised in 1904 is returned as 534 tons. A small quantity of similar material and of common pottery clay is raised also in the Central Provinces and in the Bengal coal fields.

Gypsum. The gypsum raised at Mangalore in the Jodhpur State is reported to amount to 3,875 tons, valued at £129.

Limestone. The principal varieties of limestone produced are the Nummulitic limestone of the Khási and Jaintia hills in Assam, the Vindhyan limestone of Sutna in Rewah and Katni in the Jubbulpore district. For the Khási and Jaintia hills the total is returned as 123,108 tons, valued at £9,496. The returns for various districts in Burma show a production of 67,461 tons, valued at £11,852.

Marble. Amongst the returns for marble the most important is that for the well-known quarries at Makrána in Rajputana, where the output for 1904 amounted to 1,034 tons, valued at £1,102. This value refers to the marble in the rough state at the quarries. The pure white Makrána marble which is largely used for ornamental purposes in Northern India brings an average price of Rs. 2-8 (3*s*. 4*d*.) per cubic foot in dressed blocks in addition to the State royalty of Rs. 1-6 (1*s*. 10*d*.) per cubic foot. For the year from the 1st April 1904 to 31st March 1905 the marble placed on the railway at Makrána station amounted to 34,746 maunds, or about 16,000 cubic feet.

Ochre. The only definite return for the ochres raised is that of yellow ochre obtained in the Panna State, which is reported for 1904 to be 625 tons, valued at £292.

Slate. Slate is raised along the belt of metamorphic rocks in various parts of the outer Himalayas, but the returns are incomplete. Those received, added to the production in the Aravalli belt of Rajputana, that of the Punjab and of the Kharakpur hills of Bengal, amount to an estimated value £4,628.

IV.—PROVINCIAL NOTES.

Assam.

THE principal minerals of value produced in Assam are the coal and oil occurring together in the Tertiary formations in the Lákhimpur district. The returns for 1904 show an increase in the output of both minerals (see tables 5 and 11). Another mineral of importance in the Province is the Nummulitic limestone formation on the southern slopes of the Khási and Jaintia hills, where limestone is quarried both for local use and for transport by river-steamers to the cement and lime works near Calcutta. The limestone quarried in this area during 1904 amounted to 123,108 tons, against 88,675 tons in 1903.

TABLE 16.—*Prospecting and Mining Licenses granted in Assam during the years 1903 and 1904.*

DISTRICT	1903.			1904.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Cachar	...	...	...	1	1,280	Coal and petroleum.
Do.	...	...	...	4	284,800	Petroleum.
Lakhimpur	...	...	...	1	...	Gold.
TOTAL	0	...	...	6	...	
Mining Leases.						
Khasi and Jaintia hills.	1	1,277	Coal	...	...	
Lakhimpur	1	2,560	Do.	...	...	
TOTAL	2	...	...	0	...	

In Baluchistan the most prominent mineral products are the Tertiary coal deposits, which are being worked at Khost in the Sibi district, and at various small collieries on the Sor Range.

Baluchistan.

The chromite deposits associated with serpentines in the Zhob and Quetta-Pishin districts were discovered only in 1901, and exploitation did not commence till late in 1903; but last year, 1904, the deposits near Khánozai produced 3,466 tons. Nothing is being done to develop the petroleum of the Province, and the numerous "shows" do not necessarily imply the existence of valuable supplies.

TABLE 17.—*Mining Leases granted in Baluchistan during 1903 and 1904.*

DISTRICT.	1903.			1904.		
	No.	Area.	Mineral.	No.	Area.	Mineral.
		Acres.			Acres.	
Quetta-Pishin .	...	...	......	1	660	Chromite.
Zhob . .	...	...	......	6	160	Do.
TOTAL .	0	...	......	7	...	......

Coal is by a long way the most important mineral produced in Bengal, the output for 1904, 7,063,680 tons, being 85·96 per cent. of the Indian total, valued at the pit-mouth at a little over one million sterling. The Behar districts of Bengal also produce by far the largest fraction of Indian saltpetre, the production of refined material for the last financial year being 164,702 cwt. The mines of Hazáribágh, Gaya and Monghyr still retain the lead amongst mica mines, sharing with those of Nellore over 99 per cent. of the Indian total output. The value of mica produced last year in Bengal considerably exceeded that of the combined production of the United States and Canada. The Barákar Iron and Steel Works, being the only one of the kind in India manufacturing iron on European lines, raises most of its ore locally, and consequently the Bengal returns for iron-ore represent 88 per cent. of the Indian total. Plans are in

Bengal.

progress now for the development of the rich and large deposits recently discovered in the Mayurbhanj State of Orissa. The only other mineral of considerable value for which we have accurate returns is the slate being quarried in the Monghyr district.

TABLE 18.—*Prospecting and Mining Licenses granted in Bengal during the years 1903 and 1904.*

DISTRICT.	1903.			1904.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Gangur State .	1	64,000	All minerals, except coal.	...	...	......
Gaya . .	...	...	......	1	15	Mica.
Singbhum .	...	...	......	2	14,080	Manganese-ore.
TOTAL .	1	...	......	3	...	......
Mining Leases.						
Gaya . .	...	...	......	1	1,557	Mica.
Manbhum .	...	...	......	1	2,165	Coal.
Santal Parganas.	2	35	Coal . .	3	3	Do.
TOTAL .	2	...	......	5	...	......

Bombay.

Bombay is about the most backward of the Provinces in the matter of minerals. Salt produced by the evaporation of sea-water on the coast, an undetermined quantity of building material, quarried mainly from the great spreads of Deccan basalt, and a small quantity of agates and other forms of chalcedonic silica in Cambay practically complete the list for the Province, although prospecting operations for manganese-ore in Belgaum and the opening up of the ancient gold workings in the Dhárwar district are reported to give promising results.

TABLE 19.—*Prospecting and Mining Licenses granted in Bombay during 1903 and 1904.*

DISTRICT.	1903.			1904.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Dharwar .	6	3,622	Gold . .	8	3,720	Gold.
Satara . .	1	...	Manganese-ore.	1	...	Manganese, copper, ochre, quicksilver.
TOTAL .	**7**	...	......	**9**	...	......
Mining Leases.						
Dharwar	...	...	......	2	2,073	Gold.
TOTAL .	**0**	...	......	**2**	...	......

Burma.

Activity with regard to minerals is more pronounced in this Province, at present, than in any other, as many as 27 prospecting licenses having been granted during 1904. The rapid expansion of the petroleum industry in the districts of Magwe, Myingyân and Pakôkku has been accompanied by prospecting in other areas where the geological conditions appear to be favourable for the storage of oil, or where signs have been reported. Ruby-mining is now practically confined to the Mogôk area under the control of the Company. Jadeite and amber are raised in some quantity in unadministered parts of the Myitkyina district, but the industries are not under any regular control. Concessions have been granted for the development on a larger scale of the alluvial tin deposits of Mergui and Tavoy. Dredging for gold in the larger river-valleys is attracting special interest in Burma at present on account of encouraging reports which have been circulated with regard to the results obtained by prospecting dredgers in the higher reaches of the

Irrawaddi. The gold reported from this source in 1904 amounted to 214·30 ounces.

The failure of coal-mining in the Shwebo district has been followed by prospecting operations in the Lower Chindwin district, where Tertiary coal is known to occur. An exhaustive examination of the coalfields in the Northern Shan States has been undertaken by the Geological Survey, and the results will shortly be published.

TABLE 20.—*Prospecting and Mining Licenses granted in Burma during the years 1903 and 1904.*

DISTRICT.	1903.			1904.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Akyab . .	1	183	Coal . .	...	...	...
Chindwin, Lower	...	...	......	1	1,344	Copper, gold and other minerals.
Kathá . .	2	1,920	Gold . .	2	1,920	Gold.
Magwé . .	4	7,680	Petroleum .	...	...	
Mandalay . .	1	3,200	Rubies, silver, mica, copper, graphite.	1 1	237 160	Iron-ore. Silver and other metalliferous minerals.
Mergui . .	1	207	Coal, iron, gold, tin.	1	640	Tin and other minerals.
Do. . .	1	6,400	Galena . .	2	12,800	Galena.
Myingyán .	6	16,944	Petroleum .	2	7,040	Petroleum.
Pakôkku . .	5	13,440	Do. . .	4	5,120	Do.
Pegu . .	1	...	Gold . .	...		
Prome . .	3	8,556	Petroleum .	1	2,560	Petroleum.
Ruby Mines .	1	...	Gold . .	...		
Shan States, Northern.	2	6,400	All minerals .	2 1	5,760 2,240	Various minerals. Gold.
Shwebo . .	1	205	Gold, silver, rubies.	1	1,802	Coal.
Carried over	29	...	......	19	...	

TABLE 20.—*Prospecting and Mining Licenses granted in Burma during the years 1903 and 1904*—contd.

DISTRICT.	1903.			1904.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
			Prospecting Licenses—*contd.*			
Brought forward	29	...	......	19	...	...
Tavoy . .	1	654	Gold, silver, copper, tin, precious stones.	3	227,744	Gold, silver, tin, etc.
Thayetmyo .	2	7,944	Petroleum .	3	20,538	Petroleum.
				1	100	Coal.
Yamethin .	...	...	......	1	3,200	Tin and bismuth.
TOTAL .	32	...	....	27	...	...
			Mining Leases.			
Akyab . .	1	1,167	Petroleum .			
Kathá . .	1	160	Gold . .			
Myingyán . .	1	1,280	Petroleum .			
Ruby Mines .	...	...	......	1	320	Graphite.
Thayetmyo .	1	1,280	Petroleum .			
TOTAL .	4	...	.. ...	1	...	...

Central Provinces.

In the Central Provinces the chief minerals raised are coal, manganese-ore and limestone; but active prospecting operations have been going on in connection with the deposits of bauxite referred to in the preceding volume of the *Records* (XXXII, 175—184), on some copper lodes in the Jubbulpore district, and on the remarkably rich iron-ore deposits near Dhullee in the Raipur district.

The low prices for manganese-ore which prevailed last year in European and American markets resulted in the restriction of output for the best grades. The only two coal mines at work are Warora and Mohpani, and the reduced output of both is explained on p. 6.

TABLE 21.—*Prospecting and Mining Licenses granted in the Central Provinces during 1903 and 1904.*

DISTRICT.	1903. No.	1903. Area. Acres.	1903. Mineral.	1904. No.	1904. Area. Acres.	1904. Mineral.
			Prospecting Licenses.			
Bálaghát . .	1	4,824	Manganese-ore .	1	134	Manganese-ore.
Bhandára . .	4	81,270	Ditto			
Bilâspur . .	...	...	......	1	3,216	Limestone.
Chánda . .	1	27,648	Coal . .	1 4 2	131,200 29,969 8,817	Iron-ore. Coal. Manganese-ore.
Chhindwara .	...	...	......			
Hoshangabád .	...	...	......	1	263	Lead, silver and copper.
Jubbulpore .	2	664	Lead, silver, copper, barytes. zinc, bismuth nickel, cobalt, antimony, limestone .	1 1 1	4,824 3,777 1,023	All minerals. Iron and manganese. Coal.
Ditto .	1	500	Iron-ore . .			
Nágpur . .	6	19,862	Manganese-ore .	5	509	Manganese-ore.
Raipur . .	...	...	......	1	129,920	Iron-ore.
Sambalpur .	...	...	......	1 1	9,753 3,334	Coal. Limestone.
TOTAL .	15			21		
			Mining Leases.			
Chhindwára .	...	...	......	1	54	Manganese-ore.
Nágpur . .	...	...	......	1	150	Ditto.
Raipur . .				1	206	Iron-ore.
TOTAL .	0	...	......	3		

Madras.

Mica-mining in the Nellore district continues to be the most flourishing amongst the mineral industries in Madras. Considerable progress has, however, been made in developing the magnesite veins traversing the peridotite masses near Salem, and active prospecting has been carried on for graphite in the Godávari district and for gold in the Dhárwar bands which occur in north Coimbatore. A small amount of work is done every year on some of the numerous corundum deposits known in the Presidency, but no signs of serious development have been shown so far. Graphite-mining in the Travancore State has developed to an important degree, the output for 1904 being valued at the mines at £16,324.

TABLE 22.—*Prospecting and Mining Licenses granted in the Madras during 1903 and 1904.*

DISTRICT.	1903.			1904.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
			Prospecting Licenses.			
Bellάry . .	...	...	......	1	1,920	Gold.
Chingleput .	1	6,839	All minerals .	1	11	All minerals.
Coimbatore	1	320	Gold . .	1	800	Gold and copper.
				3	2,290	Gold.
Kistna . .	1	1,345	Copper.			
Kurnool . .	3	11,589	Do.			
	1	1,526	Diamonds.			
Malabar . .	1	578	Quicksilver.			
Nellore . .	2	202	Mica . .	8	392	Mica.
Nilgiris . .	1	29	Gold . .	1	29	Gold.
Salem . .	1	7	Do. . .			
	1	21	Corundum and precious stones.			
TOTAL .	13	...	......	15		

TABLE 22.—*Prospecting and Mining Licenses granted in the Madras during 1903 and 1904*—contd.

DISTRICT.	1903.			1904.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Mining Leases.						
Coimbatore .	1	160	Gold and copper.			
Nellore . .	...	...	......	13	897	Mica.
TOTAL .	1	...	.....	13	...	.

Besides the regular mining for coal and salt in the Salt Range and the quarrying of slate in the Kángra district, active prospecting operations for alluvial gold have been commenced in the Indus valley in the Attock district, and attempts are being made to open up the stibnite lodes near the Shigri glacier in Lahaul.

Punjab.

TABLE 23.—*Prospecting and Mining Licenses granted in the Punjab during the years 1903 and 1904.*

DISTRICT.	1903.			1904.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Jhelum . .	...	...	......	7	13	Coal.
TOTAL .	0	...	......	7	...	......
Mining Lease.						
Kángra . .	...	...	......	1	320	Stibnite and Galena.
TOTAL .	0	...	......	1	...	

The principal mineral industry in the United Provinces is the quarrying of the well-known Vindhyan sand stone in the Mirzapur district. In the Himalayan districts slate is quarried in the zone of rocks which stretch along the southern face of the range through Simla and Kángra. Gold-washing on a small scale is carried on in the Bijnor, Garhwál and Naini Tál districts. Prospecting operations have been conducted on some of the well-known copper-ore deposits in Garhwál and Almora.

United Provinces.

TABLE 24.—*Prospecting and Mining Licenses granted in the United Provinces during 1903 and 1904.*

DISTRICT.	1903.			1904.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
			Prospecting Licenses.			
Almora	...	...	......	2	2,075	Copper.
Garhwál	3	9,084	Copper	...	...	......
TOTAL	3	...	......	2	...	......
			Mining Lease.			
Almora	...	...	......	1	40	Copper.
TOTAL	0	...	......	1	...	......

The British district of Ajmer-Merwára in Rajputana lies in the Aravalli belt of schists and associated intrusive rocks. Besides the quarrying of building stone and marble, of which several varieties are known in this area, prospecting operations have been conducted for mica and asbestos, but work has not so far passed beyond this stage.

Rajputana.
Ajmer-Merwara.

TABLE 25.—*Prospecting Licenses granted in Ajmer-Merwára during the year 1903 and 1904.*

DISTRICT.	1903.			1904.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Ajmer . .	...	...	...	1	10	Asbestos.
Merwara . .	1	105	Copper, asbestos and mica .	1	16	Mica.
...	3	232*	Mica . .	...	...	...
TOTAL .	4	...	...	2	...	...

The total number of mineral concessions granted during 1904 was thus 151, of which 26 were exploring licenses, 92 prospecting licenses and 33 mining leases. This represents a substantial increase on all other years, the previous record being 105 in 1902, including 16 exploring licenses. The numbers for the last ten years are shown in table 26.

Number of Mineral concessions granted.

TABLE 26.—*Number of Licenses issued for the ten years 1895—1904.*

YEAR.	Mining and Prospecting licenses.	Exploring licenses.	TOTAL.
1895	59	1	60
1896	80	1	81
1897	52	4	56
1898	85	1	86
1899	47	13	60
1900	61	11	72
1901	89	15	104
1902	89	16	105
1903	84	16	100
1904	125	26	151

PLEISTOCENE MOVEMENT AS INDICATED BY IRREGULARITIES OF GRADIENT OF THE NARBADA AND OTHER RIVERS IN THE INDIAN PENINSULA. BY E. VREDENBURG, A.R.C.S., *Deputy Superintendent, Geological Survey of India.* (With Plates 1—4.)

THE geographical peculiarities and complicated geological structure of the Narbada river have long attracted the notice of the scientific world. The remarkable mammalian fossils occurring in the strata underlying the alluvial plain that extends from Jabalpur to Handia have, from the time of their first discovery, evoked a great amount of interest which was still further increased when it became known, as the result of some boring experiments, that this formation, although belonging to a very late geological period, occupies a rock-basin of considerable depth.

Amongst the geologists who have paid special attention to this matter may be mentioned J. G. Medlicott, W. Theobald, H. B. Medlicott and Dr. W. T. Blanford.

The literature of the Narbada region is very extensive. The following is a history of the question dealt with in the present paper so far as I have been able to make out from references met with in previous publications of the Geological Survey of India.

In 1860, Mr. J. G. Medlicott drew attention to the low gradient of the river as it traverses the alluvial plain, as compared with its much steeper fall both above and below (*Memoirs*, Vol. II, page 118). In the same volume Mr. Theobald gave a detailed description of the bone-bearing beds and of their fossil remains (pages 279—298). The distinctness of the newer alluvium and its unconformity to the older bone-bearing beds was clearly recognised. The latter are regarded as of lacustrine origin.

In 1868, the Narbada formation is mentioned by Dr. Oldham in connection with an agate-flake discovered by Mr. A. B. Wynne in the alluvial deposits of the Godávari (*Records*, Vol. I, pages 65-69). In this paper the ossiferous strata of the Godávari are considered to be contemporaneous with those of the Narbada, and Dr. Oldham adopts

Falconer's provisional reference of both deposits to the pliocene period.

The next important mention is, in 1869, by Dr. Blanford (*Memoirs*, Vol. VI, pages 184-189, 227-234, 246, 276, 284-285). In addition to the alluvial formations of the Narbada, those of the Tápti and Purna are also dealt with. Dr. Blanford confirms most of the statements previously made by J. G. Medlicott and Theobald, though differing from the latter in ascribing to the gravels and clays a purely fluviatile and not a lacustrine origin.

In 1873, Mr. H. B. Medlicott refers again to the question of the ossiferous deposits in connection with the discovery, by Mr. Hackett, of a prehistoric implement apparently occurring in the same deposits that contain the extinct mammalian fossils (*Records*, Vol. VI, pages 49-54). The great depth of the ancient alluvium had not then been recognised, and its total thickness was estimated at not much more than what is seen above the present level of the river-bed, implying only a small amount of physical change since the strata were first accumulated. The importance of the unconformity between the newer alluvium and the older fossiliferous beds originally recognised by Mr. Theobald is minimised, and, considered in conjunction with the presence of human remains, is taken to indicate an age not older than newest pleistocene, in opposition to the view expressed by Falconer and supported by Dr. Oldham as to the pliocene age of the beds.

It may be mentioned that no other instance has been recorded of the occurrence of human remains in the older Narbada formation, and that, in this case, as in the previous one of the agate-flake found in the alluvium of the Godávari, there must remain some doubt, until further confirmation, as to whether the stone implements were really derived from the older beds and not from the unconformably overlying newer alluvium from which they may have slipped to a lower level during the process of denudation and become apparently incorporated with the older formation.

The ancient alluvium is also incidentally mentioned, in 1873, by Mr. H. B. Medlicott in connection with the survey of the Sátpura coal-field (*Memoirs*, Vol. X, page 184). Mr. Medlicott recommended sinking borings in order to test the possible northward extension of the Mohpáni coal-seams beneath the Narbada alluvium. The localities selected for the borings were at Gadarwára and Sukakheri, respectively 10 and 4 miles from the edge of the alluvial plain. The second of

these two borings was carried to a depth of 491 feet without reaching the underlying rock, in spite of its close proximity to the edge of the alluvial basin. This totally unexpected result altered some of the views held until then regarding the nature of the older alluvium of the Narbada plain. The great depth of the ossiferous formation indicates physical changes far more important than had originally been suspected, indicating, for the formation, an age far exceeding the very modern date which had been assigned to it.

The question under its new aspect was again treated, in 1875, by Mr. H. B. Medlicott in a review of the coal exploration in the Narbada region (*Records*, Vol. VIII, pages 65—67).

The first edition of the Manual of the Geology of India, by H. B. Medlicott and W. T. Blanford (1879), contains a full summary of the information available up to the date of its publication (pages 382—387; 2nd edition, pages 395-400).

Meanwhile the collections of fossil vertebrates from the Narbada series had been considerably added to. They were described with great detail by Lydekker in the *Palæontologia Indica*. The question of age is incidentally referred to, and the conclusion arrived at by Lydekker is intermediate between the two extreme views previously held: the formation is regarded as lower pleistocene, an attribution which all subsequent evidence, direct or indirect, has contributed to strengthen.

Of particular interest, in this connection, are the researches of Pohlig which have definitely confirmed the previously suggested conclusion that one of the principal Narbada fossils, *Elephas namadicus*, is one of the numerous varieties of the widespread *Elephas antiquus*, one of the most characteristic fossils in the newest pliocene and early pleistocene of Europe, thus establishing an important link between the pleistocene fauna of Europe and that of India. The question is fully dealt with by Mr. G. E. Pilgrim, in describing a gigantic elephant skull which he obtained in the Godávari (*Records*, Vol. XXXII, pages 199-218).

The accumulation of ossiferous gravels and clays, and the crust deformations that must be supposed to have taken place in order to account for their position within a deep rock-basin, are but the last chapter in a very complicated history. The existence of the rock-basin presupposes the excavation of a river-valley anterior to the age of the ossiferous beds which subsequently filled it. Not only has the

warping which caused this accumulation considerably disturbed the equilibrium of the Narbada and other rivers, as will be shown in the sequel to these remarks, but the question is still further complicated by denudation of the Deccan Trap, both previous and subsequent to the deposition of the ossiferous beds.

The removal of the comparatively easily-weathering Deccan Trap, by exposing the remnants of pre-trappean land-surfaces whose configuration is no longer adapted to the present system of drainage, has given rise to irregularities of a very complex character. Mr. H. B. Medlicott was the first to draw attention to this complex aspect of the question.[1] In the General Report for 1902-1903, some geographical peculiarities of this kind exhibited in the Dhar Forest region are briefly referred to as resulting from this want of adaptation between the present drainage system and the previously delineated topography (page 21).

Leaving aside this more complex and obscure part of the question, it may be observed that the changes in the relative altitude of various parts of the Peninsula, that were the immediate cause of the deposition of the pleistocene alluvial beds, have very distinctly affected the configuration of several of the river-systems of the Peninsula.

The accompanying diagrams (Plates 2 and 3) may appear to be of some interest, as they clearly illustrate the great irregularity in the rate of fall of some of the Indian peninsular rivers, and the evident connection that exists between these variations of gradient and the presence of the ossiferous formation. In these profiles, the horizontal distances are measured along the actual river-beds, taking into account their more important windings. The vertical co-ordinates show the corresponding altitudes on an exaggerated scale. In the diagram of the Narbada, the shaded portion represents the depth of the ossiferous formation so far as indicated by the Sukakheri boring which, although nearly 500 feet deep, did not reach the underlying rock. In the case of the Tápti, its tributary the Purna, and the Godávari, the diagrams show the same increase of gradient where the rivers emerge from the plains occupied by the outcrop of ancient ossiferous strata. In none of these, however, has the depth of the rock-basin been tested by boring.

The extreme divergence of these profiles from the regular curve

[1] *Rec., Geol. Surv. Ind.,* Vol. VIII, page 67.

normally assumed by a river-course after long-continued denudation scarcely needs any comment. In the case of the Narbada, the profile from Handia to Broach, leaving minor irregularities out of account, is almost a straight line, resembling far more an inclined plane than the usual curved profile of most river-courses with their gradually decreasing fall. From Handiá to the sea, a distance, measured along the stream-bed, of a little over 300 miles, the fall is about 900 feet. For the 300 miles above Handia the total difference of level is scarcely more than half the above amount. The nearly rectilinear course of the river from Handia to the sea is another remarkable feature which cannot help striking one on inspection of a map. Together with the deep and narrow gorge through which the river flows for the greater part of this section, the absence of regular and pronounced windings is quite in harmony with the relatively recent age of the changes that have affected the river-system. It is not yet possible to lay down with certainty all the details of the previous history of the Narbada, but the facts, so far as they are already known, fully bear witness to an extensive deformation of the Peninsula in late geological times. As in all cases where the evolution of a river-system is still unfinished, and sufficient time has not yet elapsed to allow the work of erosion to smooth down the obstacles caused by the different degree of resistance to denudation of the various rocks which the river meets in its course, the geological divisions are very clearly marked by various physical features. One of the best known is the waterfall at Dhári, where the river passes from the outcrop of a thick band of Vindhyan shales (probably identical with the Jhiri shales of Vindhyan nomenclature), on to the underlying sandstone dipping upstream and, thereby, forming a rock-barrier. Rapids and waterfalls exist at many other points, though their connection with the geological structure has not always been so clearly elucidated as in the case of the Dhári fall (Plate 4).

The curves are no less remarkable in the case of the Tápti, its tributary the Purna,[1] and the Godávari, and although, in the case of

[1] On the map illustrating Dr. Blanford's geological description of the Narbada and Tápti valleys, in Volume VI of the *Memoirs*, the alluvial plains of Berar and Khandesh are shown joined together by a narrow neck of alluvial deposits which has been reproduced in the maps illustrating both editions of the Manual of the Geology of India. It is doubtful whether any ancient alluvium exists in this position: the lower portion of the course of the Purna, where this connection was

the latter river, I have not been able to obtain any accurate levels for the portion of its course traversing the Nizam's Dominions, the co-ordinates obtained from the altitudes recorded from Nasik to Paitan give so shallow a curve that there must be a very marked steepening of gradient between the latter locality and the sea. Whether the ancient alluvium in the plain of the Upper Godávari occupies a rock-basin similar to those underlying the Narbada, Purna and Tápti areas has never been verified, as this region has scarcely been explored geologically. Most of the observations made on the ancient deposits refer to the neighbourhood of Nasik and Paitan, both of which are so near the border of the alluvial area that the frequent outcrops of underlying rock observed at those localities do not affect the possibility of the existence of a deep basin towards the centre of the alluvial plain. The enormous depth of the ancient alluvium of the Narbada was never suspected before it was revealed by the Sukakheri boring. In any case, the peculiarities of the profile of the Godávari, in the portion of its course occupied by the ancient ossiferous beds, are so similar to those observed in the diagrams of the other rivers that a similar explanation must be sought to account for them.

According to the most generally accepted explanation, a general tilting of the Peninsula, by means of which its western side was uplifted more than its eastern portion, would account for the formation of the rock-basins.[1] Though this explanation might account partly for some of the features observed in the alluvial plains of the Narbada, Tápti and Purna, all of which are westward-flowing rivers, it will not satisfy the case of the eastward-flowing Godávari, for, whether or not the alluvial formation of that river is situated in a

supposed to exist, had not been closely examined, and it was subsequently noticed that the Purna flows on rock in the interval between the two plains. A footnote to that effect was inserted in the Manual (1st edition, page 383; 2nd ed., p. 396). In this note the difference of altitude between the lower end of the plain of Berar and the upper extremity of that of Khandesh is given as probably not more than 100 feet. Though the difference of level is not great, it occurs within a horizontal distance sufficiently short to cause a very distinct steepening of gradient, as is clearly indicated by the altitudes recorded on the topographical map. The declivity is perhaps not sufficient to cause the formation of any rapids or waterfalls and has not, therefore, attracted any attention, but the increase of fall is sufficient to cause a very decided break in the regularity of the curve.

[1] Manual of the Geology of India, 1st edition, pages 377 and 384; 2nd edition, page 397.

rock-basin, its widespread occurrence over a flat area in which the fall of the river is very slight, sufficiently indicates a retardation in its flow similar in kind, if not in amount, to that which has affected the westward-flowing rivers. An explanation must, therefore, be sought that will account for the retardation of the rivers flowing eastward as well as for those that flow in the opposite direction. It is evident that a uniform tilting that would raise the western edge of the Peninsula in such a manner as to retard the flow of the Narbada, Purna, and Tápti would accelerate that of the Godávari. An extensive, though shallow, warping of the surface along certain definite lines and varying locally in direction and intensity would provide a more satisfactory explanation. On this hypothesis, it is very interesting to notice that the formation of a single shallow anticlinal ridge running west of the western termination of the Narbada and Purna plains with a strike slightly east of north would suffice to account for the accumulation of the ancient alluvium in three of these plains—those of the Narbada, of Berar, and of the upper Godávari. A parallel ridge would account for the formation of the plain of Khandesh (see the map, Plate I). Such a similarity of origin for three at least of the most remarkable plains accounts very satisfactorily for the remarkable uniformity of the fossil fauna contained in the ancient strata occupying them, and its evident relation to one definite geological age, which we cannot be far wrong in regarding as lower pleistocene. It has already been mentioned that this was the opinion advocated in the *Palæontologia Indica* by Mr. Lydekker, who classed together all the synchronous ancient deposits in the valleys of the peninsular rivers under the name of "Narbadas," uniting them into one series newer in age than the "Siwaliks."

It should be noticed that if the accumulation of the old alluvium is to be explained, not by a uniform tilting of the Peninsula, but by a warping resulting in the formation of definite shallow ridges, the symmetrical situation, with respect to one of the supposed ridges, of the alluvial areas along rivers flowing in opposite directions, indicates that the main directions of drainage of the Peninsula had already been outlined when this warping began to take place. It does not necessarily follow that the present river-systems conform exactly to those of the pleistocene. It is quite possible, for instance,

[1] 1st edition, page 385; 2nd edition, page 398.

as suggested in the Manual of the Geology of India,[1] that the Narbada and Tápti did not then exist as independent river-systems as at the present day: the present lower Tápti may represent the original lower Narbada, the unity of the primitive river-system having been broken up as a result of crust deformations. It is true that the data available are still insufficient to decipher every stage of the past history of these rivers. At any rate, it is difficult to think that the lower Narbada from Handia to the sea can be otherwise than of very recent age. As already mentioned, its almost perfect straightness on a map is no less singular than the almost rectilinear profile of its gradient throughout that same part of its course. It is almost certain that the portion of the Narbada situated above Handia has been tapped by a river, whose head-waters have been gradually receding further from the sea, until they encroached upon the drainage area of the original Narbada. The diversion of the lower Narbada from its former course may thus be regarded as a case of capture of one stream by another, such as is known to have taken place in so many river-systems. No doubt the changes of level that disturbed the equilibrium of the rivers have caused, or at least accelerated, this diversion, but, to account for it, there is no necessity to assume, as has been done in the 2nd edition of the Manual (page 400), that the diversion represents the overflow of a lake formed by the actual ponding back of the drainage. It is not impossible that temporary shallow lakes may have been formed, though, as pointed out by Dr. Blanford, there is no evidence that any of the Narbada deposits are lacustrine. At all events, both the formation of the rock-basin and the diversion of the river may be accounted for without supposing that any lake ever existed. The portion of the Narbada extending upstream from the "Marble Rocks" near Jabalpur to its source at Amarkantak probably corresponds with the original course of the river. Below the point where it enters the alluvial plain, near Jabalpur, the present river can only correspond in its main direction with its former course, for the ancient bed lies buried beneath the alluvium filling the rock-basin. Mention is made, in the Manual, of the extension of the alluvium to the south-west towards Harda, as probably indicating the position of the former course through which the Narbada joined the present valley of the lower Tapti.[1] Since the exhaustion

[1] 1st edition, page 385; 2nd edition, page 398.

of the forces that caused the warping of the surface, the gradual lowering of the rock-barrier at the points where the Narbada and the other rivers emerge from their rock-basins, allows the old alluvial formations to become re-denuded at a gradually increasing rate. In many parts of the Narbada plain the present upper surface of the older alluvium is situated at a hundred feet above the actual river-level. It is probable that, at the upper extremity of the Narbada plain, the ancient alluvium extended, at one time, higher than the level of the Dhuán-dhára, a small waterfall situated just above the "Marble Rocks." The famous gorge of the Marble Rocks is perhaps not the original bed of the Narbada, but may represent the situation of a portion of a subsequent bed established, for a time, upon a portion of the alluvial formation now denuded away. When the river, in this part of its course, eroded its new bed deep enough to reach the underlying rock, it probably did not meet again with its former channel, and the present gorge has been excavated through what may have been a low ridge before the pleistocene beds had been deposited. The waterfall at Dhuán-dhára appears to indicate that the level of the river at the head of the alluvial area has now been lowered sufficiently to commence causing a distinct increase in the erosive power of the water in the upper portion of the river-course.

The same set of causes, to which may be attributed the formation of the broad alluvial plains of the Narbada, Tápti, Purna and Godávari, will account also for smaller alluvial plains along the valleys of the Kistna and some of its tributaries. They have been mapped and described in the geological account of the South Mahratta country[1] by Mr. Foote, who discovered in one of them the fossil remains of a remarkable extinct species, *Rhinoceros deccanensis* Foote.[2] The topography of the Kistna and its tributaries is not contoured with sufficient detail in the maps at my disposal, to allow the construction of approximate profiles. Were this possible, they would probably reveal some irregularities of the same kind as those exhibited by some of the other rivers.

In other instances, owing either to a lesser intensity of the warping, or to a different situation of the river-bed relatively to the direction of disturbance, the physical changes, though sufficient to give rise to

[1] Mem. Vol. XII, pages 237, etc.

[2] For a description of this fossil, see *Palæontologia Indica*, Ser. X, Vol. I, part I.

some discontinuous patches of fossiliferous alluvium, have left no permanent impress upon the profile of the rivers. Such is the case with the Pemganga, whose profile does not appreciably differ from that assumed under normal conditions of erosion, although patches of pleistocene alluvium are disseminated in various parts of its valley and in the valleys of some of its tributaries. At the same time the profile of the Mahánandi river, from whose valley no pleistocene gravels or clays have been ever recorded, differs, nevertheless, to some extent, from the normal curve of denudation. Whether the slight steepening of gradient that takes place at some distance from the sea, as expressed in the diagrammatic profile by a bulge above Sambalpur, is due to the same warping that caused the deposition of the ancient alluvium in other valleys, or whether, as in the case of the African rivers, it is a general feature amongst the Indian peninsular rivers, indicating a general rise of the peninsular platform relatively to the sea-level, and independent, perhaps, from the more complicated warping that has caused the formation of the rock-basins, is a question for the investigation of which sufficient data do not seem available. At any rate, all these changes agree in showing that a very extensive, though moderate, disturbance has affected the Peninsula at a late period previous to recent times. It will be asked, perhaps, how it is that no indication of this warping should have been noticed in the nearly horizontal Deccan Trap formation? But it must be remembered that, while its effects may seem very evident on the diagrammatic profiles of the river-courses, with their enormously exaggerated vertical scale, the amplitude of the oscillations relatively to the large areas affected is so small that it would, no doubt, require a minutely detailed survey to detect any consequent tilting of the volcanic beds. The Deccan Trap area is, from a geological point of view, almost a blank. Where the beds are very distinctly tilted, as in the Rájpipla hills, or in some parts of Kach and Káthiáwár, the disturbance is probably related to the Himalayan period of orogenic movements, and therefore anterior to the post-Himalayan period of the "Narbada" series.

Side by side with the profiles of the Indian rivers, I have placed that of the Rhine,[1] whose exceptional features are also largely due to crust movements that took place in the pleistocene period. The

[1] This diagram is taken from one of the figures in Lapparent's "Leçons de Géographie Physique." It has been adapted to the same horizontal and vertical scales as the profiles of the Indian rivers.

plain occupied by pleistocene alluvium that extends for many miles above Mainz, and the steeper portion of the river-course commencing below that town, correspond, respectively, with the portions of the Narbada situated above and below Handia. The formation of the lake of Constance is also a result of tectonic influences, but, in this case, the formation and preservation of the rock-basin have been greatly assisted by the protecting covering of ice during the glacial period, so that it is not so strictly comparable with the rock-basins of the Indian valleys as the alluvial depression of Mainz.

The origin of many features of northern topography has been ascribed to similar causes acting at that same period: for instance, the Swiss lakes, and those of North America, though it is, to a large extent, the glacial conditions which, by retarding or arresting the erosive power of the rivers, allowed the formation of rock-basins. It has been suggested that this warping of the surface, in northern latitudes, during the great ice age, is a direct result of the presence of ice. It is interesting, therefore, to find that in peninsular India, where glaciation, at that time, is out of the question, similar effects have taken place at a period which, as indicated by the fossil fauna, corresponds with that during which the crust-movements took place in Europe and in America. This simultaneous occurrence of earth-movements strengthens the idea that the ice had little more influence than to preserve the effects of this deformation. The pleistocene period seems, therefore, to have witnessed a warping of the earth's crust which, though not to be compared, in its effects, with the gigantic orogenic efforts of the Tertiary era, appears, nevertheless, to have been remarkably widespread. In India, the conditions for a detailed study of this interesting question should be particularly favourable, for the case here is not complicated by the presence of the glacial moraines and boulder-drift, which, in northern latitudes, have had frequently as great an influence as the crust-movements in altering the drainage system. In consideration of the synchronism that has been recognised between the great orogenic movements of the Alps and Himalayas, the idea that the pleistocene disturbance in India was partly simultaneous with that which affected so large a portion of the northern hemisphere is a view that commends itself, though it cannot be insisted on without further evidence. The regions intervening between the better known areas of Europe and India have not yet been sufficiently studied to institute a precise correlation Post-pliocene movements

seem evident in Baluchistan and in Persia, and may account partly for the present isolation of most of the drainage of those countries, but the data are insufficient to determine either the importance, or exact age of those movements. One would also like to know how these ancient peninsular fluviatile deposits are related in age to the "karewas" of Kashmir and the deposits of the "duns," and to those of the plains of Tibet. But here, too, information is insufficient to lead to any definite conclusions, and one can only draw attention to the interest of these questions. In the peninsular area itself there are, in the neighbourhood of the sea-coasts, many deposits of late geological date, whose exact correlation cannot be settled, as they are either unfossiliferous, or else contain nothing but molluscan remains, whose value for determining their exact age is far less precise than that of the rich mammalian fauna of the Narbada series.

The supposed existence of a fault along the foot of the Western Ghats is again a question that invites attention in this connection. Supposing the abrupt linear escarpment that limits the Peninsula to the west to be really a fault of relatively modern date, one would like to know whether it stands in any relation to the crust-movements that caused the accumulation of the Narbada series, whether it accompanied or preceded the warping, and whether it is really part of the same set of phenomena. This is also one of the Indian geological problems that still await further elucidation.

There exists very little information regarding another question of great importance and interest, that is, the relative age of the older parts of the Ganges alluvium compared with that of the Narbada series. It is quite conceivable that the same disturbances that affected the peninsular rivers should also have influenced some part of the Ganges and Jumna area. But while, on the one hand, since the close of the period of disturbance, the peninsular rivers have all become eroding streams, on the other hand, deposition has remained continuous in the Ganges valley, and the difficulty of distinguishing older from newer alluvium is thereby considerably increased. Bones of extinct mammalia were found about 1830, in the banks of the Jumna.[1] Vertebrate fossils have again been discovered quite lately at Allahabad, while sinking wells for the foundations of a new viaduct across the Ganges. The fossils, which were described by Mr. Pilgrim in a

[1] Manual of the Geology of India, 1st edition, page 402; 2nd edition, page 436.

recent number of these Records (Vol. XXXI, pages 176-177), occur at some depth below the present river-level, and it is conceivable that sedimentation may have gone on uninterruptedly since they were entombed. But, in the case of the Jumna, the fossils occur above the present river-level, and although, in our present imperfect state of knowledge concerning the history of the Ganges system, this cannot be regarded as an absolute proof of disturbance, yet it strongly suggests it. These two finds are the only ones as yet recorded from the Gangetic alluvium, of which the specimens have been identified, and these fossils are too few to form a complete idea of the fauna. Some of them are identical with forms occurring in the peninsular alluvial beds, but several of the commonest extinct mammalia of the Narbada series are absent, while it also happens that a species, such as *Bos namadicus*, F. and C., common to the deposits of the peninsular rivers and to those of the Gangetic plain, exhibits, when found in the latter, varietal modifications that seem to suggest a newer age. The authors of the Manual were of opinion that the Gangetic fauna is somewhat newer than the Narbada one. In the case of the peninsular rivers, the accumulation of the ancient fossiliferous beds could only have taken place at the particular period when the warping occurred, with the consequence that, wherever present, these gravels belong to one age; but in the case of the Ganges alluvium, as deposition has been continuous, the formation may contain, at various depths, strata both older and newer than the Narbada series. Thus, if there has been, within the Gangetic area, any warping that could raise portions of the older alluvium sufficiently to cause their re-appearance at various localities, it does not follow that the different outcrops are all of one age. It is possible that, in the Gangetic area, the supposed crust-movements, of which we only possess somewhat obscure evidence, are of post-Narbada age, and that their amplitude has never been sufficient to raise to the present surface any strata synchronous with the Narbada series. This would account for the somewhat newer age that has generally been ascribed to the Gangetic fossils. Still, it is not yet possible to pronounce very definitely on this subject, which must be added to the list of the many unsettled questions referring to the last chapters of the past geological history of India.

ON RECENT CHANGES IN THE COURSE OF THE NAM-TU RIVER, NORTHERN SHAN STATES. BY T. D. LATOUCHE, B.A., F.G.S., *Superintendent, Geological Survey of India.* (With Plate 5.)

THE accompanying map, taken from a portion of sheet 332 of the Upper Burma Topographical Survey, shows a portion of the course of the Nam-tu (Myitnge of the Burmese) and Nam-ma rivers in the neighbourhood of Hsipaw (Thibaw), the capital of one of the Northern Shan States. A glance at this map will show that about six miles above Hsipaw, the Nam-tu, which is the larger river of the two, enters the Nam-ma at right angles, as if it were a mere tributary of the latter. As we cross the railway bridge at the junction of the two rivers, on the journey from Hsipaw to Lashio, and catch a glimpse of the comparatively narrow valley, down which the Nam-tu flows, and, moreover, when we note the slight change, if any, in the dimensions of the valley of the combined rivers below the junction, and that of the Nam-ma above it, it is difficult to realise that the former is the main river, and we naturally endeavour to seek some cause for this peculiar feature. This feeling of there being something anomalous in the course of the Nam-tu is intensified when we find that the river, between Tati ferry and the junction with the Nam-ma, cuts directly across the strike of the rocks, which are here sandstones of Mesozoic age, running in highly inclined beds from north-east to south-west.

Looking north-eastwards from Hsipaw towards Tati, where the Nam-tu debouches from a deep gorge cut through hard rocks of Palæozoic age, and enters the softer Mesozoic sandstones, we see a broad open valley, now watered by several insignificant streams, almost dry during the hot season, and closed at its upper end, between three and four miles from Hsipaw, by a low range of hills. If we cross these hills by the road leading from Hsipaw to the Tati ferry, we find that the surface of them is a broad, nearly level plateau, strewn with boulders and pebbles of the Palæozoic rocks through which the Nam-tu flows in the upper part of its course, and that the greater part of these hills is made up of the same water-worn material, mixed with clay

and sand. They are, in fact, the remnants of an ancient terrace of gravel and boulders, rising to a height of 100 to 150 feet above the present level of the river at Hsipaw, and they can only have been laid down by the Nam-tu, for, of the smaller streams which drain the hills to the west of the valley, only one or two reach the area from which the rocks composing the boulder terraces are derived, and these drain only a very small portion of it. Another point to be noticed is that, beneath the covering of boulders, there are traces here and there of the rocks beneath, forming the old floor of the valley, and at a higher level than the present river valley.

The sequence of events that led to the present alignment of the river-courses appears to have been as follows. In former times the Nam-tu, debouching from the hills of harder rock just above Táti as at present, flowed south-west to Hsipaw and excavated a broad open valley in that direction, the natural continuation north-eastwards of the present valley of the Nam-tu between Hsipaw and Bawgyo, while the Nam-ma, following its present course, joined the main river near Hsipaw.

This broad valley extends as far as the mouth of the Nam-hsim, at which point the Nam-tu turns sharply to the south, and runs for a long distance, across the strike of the rocks, through a comparatively narrow gorge. The deepening of this gorge was naturally a slow process, and, while it was going on, the river above Nam-hsim reached a stage of equilibrium, its 'regimen' so far as this portion of its course was concerned, and began to deposit silt and boulders on the floor of its valley, gradually raising its bed to at least the level of the terraces, the remains of which may be traced along the edges of the valley between Hsipaw and Nam-hsim, at considerable heights above the present level of the river.

At the same time the small streams flowing into the main rivers above Hsipaw across the strike of the rocks had been cutting down their channels, and finally two of them,—one flowing south into the Nam-ma at the point where the Nam-tu now joins it, and the other north-west into the Nam-ma near Táti,—reduced the divide between them to a point at which it was on a level with, or below, the bed of the Nam-tu, where it flowed over the boulder terrace laid down by itself between Tati and Hsipaw. Any slight obstruction then, a more than usually heavy deposit of boulders, for instance, in the main river, or an accumulation of drift-wood, would be sufficient to divert the flow into its

present course, and the increased fall would cause it to cut back rapidly into the deposits formerly laid down by it, and render the deflection of its course permanent. By the time this happened, the gorge below Nam-hsim was sufficiently lowered to allow the river to excavate the terraces already deposited by it in the Bawgyo valley, and the present configuration of the valley was the result.

EXPLANATION OF MAP.

The map shows a portion of the country in the neighbourhood of Hsipaw, North Shan States, on a scale of 2 m.=1 in.

The north-west corner is occupied by sandstones and shales of Silurian and Ordovician ages. These are succeeded by a band of limestones, probably of Devonian or Carboniferous age. These in turn are succeeded by sandstones with bands of fossiliferous limestone and conglomerates near the base, probably separated from the limestones below by an unconformity. The fossils show that they are Mesozoic.

The Nam-tu and Nam-ma have excavated a broad valley in the sandstones partly filled with terraces composed of gravel and boulders. The probable course formerly taken by the Nam-tu between Tati and Hsipaw is shown by a blue line.

NOTE ON THE NATURAL BRIDGE IN THE GOKTEIK GORGE. BY T. D. LATOUCHE, B.A., F.G.S., *Superintendent, Geological Survey of India.* (With Plates 6—9.)

ONE of the principal obstacles to the construction of the Mandalay-Lashio railway, originally intended to connect Burma with S. W. Yunnan across the Northern Shan States plateau, was the existence of a deep gorge with almost perpendicular sides, about midway between Maymyo and Lashio. This gorge, known to the Shans as Hokut, and to the Burmese and Europeans as Gokteik, lay directly across the line of advance of the railway, and there was no possibility of avoiding it, for on the south it joins the far deeper and equally precipitous gorge of the Nam-tu or Myitnge river, while to the north the country is a maze of lofty ridges separated by deep narrow valleys, through which it would have been quite impossible to carry the line.

This gorge has been excavated through the limestones of the Shan plateau by the united waters of two large streams, the Nam-pan-hse, and the Nam-tang, which drain the hilly country to the north. At Chaungzon (the meeting of the waters) the depth, measured from the surface of the plateau at Nawnghkio, is about 1,500 feet, which gradually increases to about 2,000 feet, at the junction of the united streams with the Nam-tu, a distance of about 10 miles. The direction of the gorge is at first east-south-east as far as the railway crossing, and then south-east.

In selecting a site for the railway viaduct advantage was taken of the fact that at about 2 miles below Chaungzon the river is spanned by a 'Natural Bridge,' the upper surface of which is 550 feet above the river, and upon this the principal pier of the viaduct, a fine structure of steel, has been founded. The greatest height of the viaduct, at the point where it rests upon the natural bridge, is 320 feet, and the total height from the bed of the stream to rail-level is somewhat under 900 feet. Thus the descent from the plateau, and the ascent to it on the opposite side of the gorge, has been reduced to about 600 feet, and though the gradients are very heavy, generally speaking about 1 in 40, they are not excessive. There are three of these natural bridges

within a distance of about a mile, and it is to the uppermost of these, the one crossed by the viaduct, that the remarks in the present paper apply.

Before proceeding to a consideration of the causes that have produced these remarkable structures, it may be well to glance at some of the explanations that have already been put forward to account for them. Thus Sir J. George Scott, describing the natural bridges in the Upper Burma Gazetteer,[1] says: "The Hokut circle is noted for the so-called 'natural bridge.' It is somewhat difficult to account for the application of the term. The Nam Hpa Se simply disappears into the ground, as the Mole does in England, and as many other streams do in the Shan States, especially in limestone formations, but there is no special feature about the ridge through which the water tunnels its way to justify the term 'natural bridge.' * * Indeed, this anastomosis[2] is quite a common feature in all parts of the Shan States."

Though the phenomenon mentioned above by Sir George Scott is of frequent occurrence in the Northern Shan States, this explanation will not account for the natural bridges of the Gokteik gorge, for the river at this point does not disappear into the solid limestone, as in the other cases he alludes to. The case is not quite so simple as that of a stream disappearing underground into a fissure and re-appearing elsewhere.

Another account of the natural bridges is given by Mr. John Nesbit in his work "Burma under British rule and before."[3] He says, speaking of the railway: "This Gokteik gorge formed, however, a very formidable natural obstruction to further progress. A fissure in the hills, incomplete in one portion, resembling rather a geological fault, apparently resulted in once damming up the bed of the Gokteik stream now lying hundreds of feet below. A lake must have been formed, until in course of time the waters forced an outlet for themselves by percolation and pressure, in the form of a subterraneous passage extending for about half a mile through the dam of limestone rock. The stream now disappears for this considerable distance into a huge cavern, while the fault above it forms a *Ngok* or natural bridge across

[1] Upper Burma Gazetteer, Pt. II, Vol. I, p. 140, Rangoon, 1901.

[2] It is hardly necessary to point out that the word 'anastomosis,' which Sir George Scott uses more than once with the same connotation, is by no means the correct term to apply to a phenomenon of this kind.

[3] Westminster: Archibald Constable & Co., Vol. II, p. 36.

which the old trade route from China to Mandalay passes. * * Natural bridges of this sort are common throughout the Shan States, where the prevailing rock is limestone."

In this passage there appears to be some confusion of ideas about the nature of a fault, for in one place it is said to be a fissure, and in another the mass of rock closing the same fissure, while it is difficult to see how a fissure could result in damming up the river. What is probably meant is a landslip, bringing down a mass of rock from the precipices lining the northern side of the gorge, which may have closed it for a time, and I was at first under the impression that such a slip may have had something to do with the formation of the natural bridges. But there is no indication whatever that a lake ever occupied the portion of the gorge above the bridges, nor have I been able to discover any traces of a fault running in the direction of the gorge.

The section of the gorge at the place where the railway crosses it is peculiar. The upper portion, down to the level of the natural bridge, has gently sloping sides on the southern bank, while the north bank is quite precipitous. This feature is due to the fact that the limestone rocks, out of which the gorge is excavated, dip towards it on the southern side, so that the tendency of the river has been to cut back the northern bank into a series of perpendicular cliffs (see section, Plate 6). But from the top of the natural bridge to the river the sides are more or less perpendicular on both sides, and very close together, so that the river runs in a deep narrow trench, invisible from above, until one is crossing the viaduct immediately above it. The effect of this sudden glimpse into the profound depths of the gorge, as the train slowly rolls across the bridge, is curious, and one not likely to be forgotten by anyone who has ever experienced it. It is difficult to conceive why this sudden change in the direction of erosion should have taken place, why the river, that is, instead of continuing to cut back along the dip-slope of the rocks, suddenly began to excavate its bed in a vertical direction, and I have not yet been able to find a satisfactory explanation of this feature. It is in this lower and narrower part of the gorge that the natural bridges have been formed.

The excavation made for the foundations of the railway viaduct in the top of the natural bridge, and in the sides of the gorge immediately above it, show that the natural bridge itself is composed to a great extent of travertine or calcareous tufa, deposited from water saturated with carbonate of lime, on the evaporation of the water.

The cuttings on the railway as it descends both sides of the gorge also show that the ground is covered, often to a considerable depth, with deposits of the same travertine. This, there is no doubt, has been deposited by the streams which flow into the gorge from either side. Great curtains of it may be seen hanging from the cliffs which line the northern bank. At the point where the natural bridges are found the deposit is particularly thick and massive, and, the precipitous sides of the gorge being very close together, the travertine has gradually grown out from the sides, from the southern side especially, forming a kind of bracket or shelf, overhanging the river, until it has met and coalesced, forming a true 'bridge' (Plate 7). At the same time the river has prevented any great accumulation of the travertine up to its flood-level, and has kept a passage open for itself. Some deepening of the gorge has probably taken place since the bridge was first formed, and this would account for the present height of the cavern, the roof of which is considerably higher than the present flood-level of the river, as much indeed as some 200 feet (Plate 8).

When once a connection had been established in this way between the opposite walls of the gorge, the growth of travertine proceeded upwards, and no doubt the talus from the cliffs above, falling on the roof of the bridge, added greatly to the rapidity of growth. When, however, the upper surface of the bridge reached the level where the streams that formed it fell over the edge of the cliffs, the water naturally began to find its way through fissures in the mass, and at the present time, instead of adding to the height of the bridge, most of the travertine is deposited on the roof and walls of the cavern, where it forms fine stalactites and stalagmites. A huge column of stalagmite, some 30 or 40 feet in height, is being formed in this way just within the entrance of the cavern, visible in the photograph (Plate 8), and is being continually added to by a small stream of water which issues from the roof of the cavern immediately above it.

As an illustration of the manner in which these natural bridges are formed, the photograph (Plate 9) is instructive. This view was taken on the Nam-ma river, south of Lashio, at Ho-hko-nam-hpak-lün, where the cart-road from Lashio to Taung-yun crosses it by a fine wooden bridge. Here the river runs through a gorge, some 50 feet deep and, as at Gokteik, two small streams join the river from either side just beneath the bridge. The travertine deposited by

these streams has formed two shelves, growing out from either bank of the river, and in shape very similar to the fungus brackets one often sees growing on a tree-trunk (see fig. 1). Here the shelves of travertine

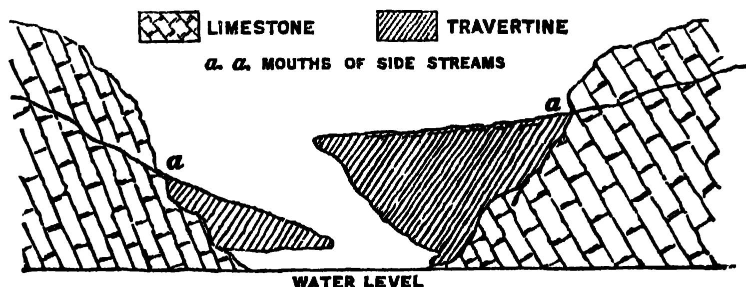


FIG. 1.—*Diagrammatic section across the Gorge of the Nam-ma at Ho-hko-nam-hpek-lün.*

have not coalesced in the middle so as to form a complete bridge, but this is no doubt due to the fact that the gorge is not very deep, and so the river, when in flood, cuts away the newly-formed travertine at the edge of the shelf. This illustration shows very clearly how the under surface of the shelf is kept from thickening by the flow of water beneath it, so that if the travertine were to grow across the gorge, an open cavern would be formed.

I am indebted to the District Engineer, Burma Railways, Mandalay District, for the section and plan of the Gokteik gorge attached to this note. I have attempted to indicate diagrammatically in the section the probable form of the mass of travertine which forms the bridge, but both sides of the gorge are so covered with it that, except where the water of the stream actually washes the rocks, it is difficult to see any solid limestone. The photograph (Plate 8) is taken from a little distance above the upper entrance to the cavern, and it may be noted that the travertine forming the roof comes down much lower on the left-hand side (north bank) than on the right. This is probably caused by the layers of travertine, as the 'bridge' was being built up, drooping over towards the north wall of the gorge, for the principal growth seems to be due to the deposits of the streams on the south bank.

EXPLANATION OF PLATES.

PLATE 6—

Fig. 1. Plan of the Gokteik gorge at the site of the railway viaduct.

" 2. Section across gorge at the 'natural bridge.'

PLATE 7—

View of the upper part of the natural bridge, and railway viaduct. The line separating the travertine of the bridge from the rocky wall of the gorge is clearly visible.

PLATE 8—

Cavern at the base of the 'natural bridge', from near the upper (western) end. At the mouth of the cavern, on the left-hand side, is a column of travertine deposited by a small stream issuing through the roof. The curtain-like form of the travertine-deposits on the walls of the gorge is well shown.

PLATE 9—

Gorge of the Nam-ma river at Ho-hko-nam-hpak-lün, south of Lashio. At either side, immediately below the bridge, small side streams have deposited 'shelves' A, B of travertine, that on the left bank (right-hand in the figure) extending more than half-way across the stream.

NOTES ON THE GEOLOGY AND MINERAL RESOURCES OF THE NARNAUL DISTRICT (PATIALA STATE). BY P. N. BOSE, B.SC. (LOND.), F.G.S.

I.—GEOGRAPHICAL AND STRATIGRAPHICAL.

THOUGH being a portion of the Patiala State, the district of Narnaul is included in the Punjab; it belongs geographically to Rajputana. It is situated between Latitude 27° 48′ and 28° 28′ and Longitude 75° 57′ and 76° 20′, and comprises an area of 605 square miles. The district is called after Narnaul, a large town with some claims to antiquity. Besides mausoleums and other stone-built edifices of the Mahomedan period at Narnaul, there are ruins extending over a distance of about 4 miles between that town and Dhosi hill, which are referable to a much earlier date, and on Dhosi hill (called *Archik* in the *Puranas*) there is a well, known as Chandrakup, which draws large numbers of pilgrims from the surrounding country, and which tradition ascribes to the earliest period of Hindu history.

There are two rivers which drain the district (when there is sufficient rainfall for drainage)[1]—the Basi and the Kasawati. They have numerous feeders in the hilly country in the southern portion of the district, but they are both blind rivers, the former being lost in the desert about 10 miles north of Kanaud, and the latter about as many miles east of that town.

The southern portion of the district is hilly, the hills running generally in a north-south direction, roughly parallel to the strike of the rocks of which they are constituted.

The highest of these hills is Dhosi, which rises to an elevation of 2,138 feet.

Desert conditions appear near Narnaul, and become more and more pronounced towards the north; and in the northern portion of the district, comprising the greater part of Kanaud tehsil, a few hills rise out of the desert, the most conspicuous of these being a range striking from near Khodana southward through Rajawas and Madhogarh to

[1] During 1905 the rainfall did not amount to more than 2 inches, and the rivers remained dry throughout the rainy season.

Sohla, and rising occasionally to a height of about 1,600 feet above the sea-level.

The district is included in the geological map which accompanies Mr. Hacket's paper on the "Geology of the Aravali region, central and eastern" (*Records*, Vol. XIV, p. 279). But there is no reference in the paper to the geology or mineral resources of the district, or of any portion of it.

Gneiss of a somewhat granitoid type constitutes Dhosi hill and the hills in the vicinity of Dhanota in the western portion of the district. It is apparently older than the well-foliated gneiss accompanying the schists of the Aravali series, which forms the hilly country in the southern portion of the district. The principal rocks which constitute the series are schistose or sub-schistose quartzites, quartz and mica schists, phyllites, and limestones usually altered into marble. The strata are highly disturbed, and, besides minor folds, are thrown into a well-marked syncline, those on the western side of the district as about Sarai, Saraili, etc., dipping eastward, and those on the eastern side as about Atri, Biharipur, Loniake, Nangal, etc., dipping westward. The dip is high, seldom less than 45°, and often approaching verticality. The strike is fairly constant varying between N. N. E.-S. S. W. and N.-S.

The hills in the northern portion of the district are formed mainly of quartzites and quartzitic sandstones or gritstones with subordinate bands of phyllite and quartzose micaceous, and occasionally calcareous, schists. They have been coloured as "Delhi Series" on Mr. Hacket's map, referred to above, and are referable to the upper group of that series known as the "Alwar quartzites." From what is seen in the district, however, there is little to differentiate them from the Aravalis, beyond the fact that they are comparatively less altered—a condition which might be attributable to the Aravalis being intruded by granite on a much larger scale than the Alwars. But as the area examined by me is very small, I am not in a position to express a definite opinion on the subject.

The granite just mentioned intrudes indifferently into the gneiss of the Dhosi hill and the schists, quartzites, gneisses and limestones of the Aravali series. It is found in great force in the area south and west of Narnaul, and gradually disappears northward, until in the northernmost portion of the district it is found to be absent altogether. The granite is very coarse-grained, and, besides being full of tourmaline, is permeated by veins of muscovite, which will be referred to later on.

II.—ECONOMIC.

1. Iron-ores.

Deposits of iron-ore occur in quantity at the following localities :—

(1) About a mile north-north-west of Sohla (Kanaud tehsil) the ore (hematite) occurs in association with highly disturbed and much crushed ferruginous quartzites.

(2) Near Dhanota (Narnaul tehsil). The ores here (hematite with magnetite) occur in association with gneiss of a granitoid type.

(3) The richest and most extensive ore-body occurs in a low ridge which runs from Chhapri (seven miles south of Narnaul) to Jaunpur—a distance of two miles and-a-half. The ore consists of magnetite with hematite. The following is an analysis of an average sample made by Dr. Schulten :—

Oxide of iron		82·03%
Equal to iron	57·42%	
Alumina		4·82
Lime		1·30
Magnesia		traces.
Sulphur		0·15
Phosphorus		0·42
Siliceous matter		9·38
Moisture		0·06
Alkalis and loss		1·84
		100·00

This assay indicates a high grade ore; and there is an enormous extent of it. The ore occurs as bands interbedded with the marble and schistose rocks of the Aravali series. Going across the strike at Antri, I encountered three bands, each averaging about 7 feet in thickness. At the southern end of the Chhapri-Biharipur ridge, however, I found only two bands of the ore. In former times the ore was in great request in the neighbourhood, and used to be carried far into Jaipur and Alwar State. A royalty of one anna per bullock-load used to be levied. There is not a single furnace now in the area.

The chief obstacle in the way of the establishment of iron and

steel works on modern western methods in the Punjab is the absence of suitable coal any nearer than Bengal. But the freight on coal for long distances has just been reduced, and further reduction may be expected in the future. Besides, iron-works in the Punjab would command the markets of that Province and of Rajputana and the United Provinces. But I doubt if iron works on a large scale are likely to be started in the Punjab in the near future, since such works require very large capital, and since a company is now being floated with a capital of two crores of rupees to work the iron ores of the Mayurbhanja State, which are similar to those of Narnaul, but are more favourably situated in respect of coal. However, such a magnificent ore-body as that of Narnaul cannot long remain unutilised, though owing to the difficulties mentioned above, it may not be worked in the immediate future.

2. Mica.

Mica (muscovite) occurs at various places in Narnaul tehsil in coarse-grained granite which is intrusive in the Aravali series. The localities which are specially noteworthy are Ghatasher, Saraili, Panchnauta and Musmuta. The area covered by these places measures about 14 square miles. The mica occurs in lenticular veins; and the mica books obtained by me attain a size of 9″ by 6″.

3. Copper-ores.

Copper-ores are very widely distributed. They occur in the Alwar quartzites as well as in the Aravali series. That they have been extensively worked in past times is evidenced by the large number of mines scattered throughout the district. They are most numerous in the southern portion of the district, especially about a village called Motaka (Mokata on maps), a ridge in the neighbourhood of this place being closely riddled by meandering galleries. I also came upon two rectangular pits there, one of which was reported to me to be 100 feet deep. The old workings, however, are generally rather shallow. Everywhere the only indications of ore met with were stains of malachite on quartz, phyllite, etc. There was no sign of the presence of rich ore anywhere.

4. Manganese.

Extensive deposits of limestone and shale impregnated with manganese oxide occur about Goela, Dargaka, Nangal, etc. They are of

some commercial importance, but their distance from the Calcutta market renders the prospect of their exploitation rather remote.

5. Rutile, Garnet, Kyanite.

In the course of the mica exploration in the vicinity of Ghatasher, the Sub-Overseer in charge of it has come upon a mineral in a somewhat massive form which has been determined by Mr. Fermor, Curator, Geological Museum and Laboratory, to be rutile. It apparently occurs in some abundance in the Aravali series, through which the mica-bearing granite is intrusive.

Garnets are rather plentiful in the Aravali schists in the hills east of Ghatasher. As a rule, however, the colour did not appear to me to be sufficiently good to render them marketable.

Kyanite occurs in bluish, thin-bladed as well as short and thick crystals usually in association with calcite in the hills just west of Narnaul. It is found in some quantity. The jewellers at Patiala called it "bruj," and informed me that it is used in jewellery, and sold at R3 to R5 per tola.

6. Limestone and Marble.

Limestone and marble occur in great profusion and variety in the district. A band of black limestone well suited for lime occurs at Dhani Bathanta, about four miles south-east of Narnaul. It is esteemed so highly that the stone sells in the Delhi market at the high price of eight annas a maund. The limestone is mostly covered by alluvium. Quarries which are about 200 feet wide have been opened into it for a distance of 300 yards. Limestone of a similar character occurs also at Baliari, 10 miles south of Bathanta, in the direction of the strike.

White and black marbles occur two miles west of Narnaul, in some hills, the highest of which are known as Mundi and Datla. They were traced for about a mile, and at one place on Datla hill the band of white marble was found to be about 125 feet thick. It has been worked to some extent to supply the architectural wants of Narnaul. I saw rectangular blocks, measuring 5′ by 2′ by 1½′, lying about the place.

About nine miles south of the hills just mentioned, white marble occurs in great force in a ridge just west of the villages of Antri and Biharipur. The marble extends over a distance of about a mile-and-a-

half. It has been worked most at Biharipur, where there are several quarries, the largest of which was found to be 150 feet long, 50 feet wide and 20 feet deep. The dip of the marble at Biharipur was found to be 50°W., and the thickness of the band which is worked there is 200 feet. It is traversed by joint planes at intervals of 4 to 6 feet.

White marble similar to that of the Antri-Biharipur ridge, and apparently belonging to the same band, occurs at Dhonkora (five-and-a-half miles south of Biharipur), where it forms a high ridge just west of the village. The marble here is more disturbed than at Biharipur, the dips being not less than 80°. It has been worked to a very small extent only.

White marble also occurs between Dhanota and Dhansoli in the south-western portion of the district, about two miles from Nizampur railway station.

Black or black and white banded marbles occur at the following localities besides Dhani Bathanta and Balian already mentioned:—

(1) Makundapur, three miles south of Narnaul.

(2) Jalanwali (near Islampur). The marble here occurs in the strike of that of Makundapur, and it will probably be found at intermediate places. The band here is traceable for over half a mile, and it has been rather extensively worked. The dip is about 40°W. The rock, I was informed, is in great request for millstones. I saw several lying about, one of which measured 3 feet 6 inches in diameter and 9 inches in thickness.

(3) Goela. Near this village, which is situated at the southern extremity of the Narnaul district, there is a band of dark-coloured slaty limestone dipping nearly vertically and easily obtainable in blocks measuring about 7′ by 4′ by 1′ to 4′. This rock has lately been worked to some extent.

7. Building stones other than marble.

(*a*) Sub-schistose quartzites of the Aravali series. These have been very extensively worked in the hills west of Begopur, one quarry being nearly 150 feet in depth. The rocks split easily along planes of lamination, which are sheeny with minute flakes of mica. The dip is nearly vertical.

(*b*) Quartzitic sandstones suited for building purposes occur at Rajawas and near Baliana in Kanaud tehsil, and at Mandlana, Kuthapur and Khaspur in Narnaul tehsil. The Rajawas and Baliana hills are dotted with pits. The rocks dip high from 45° to near verticality. Slabs measuring 6′ by 1½′ by 6″ are available. The sandstones at Mandlana, where they form a low ridge quartzitic, have also been very largely worked, being in great demand at Narnaul and its neighbourhood.

MISCELLANEOUS NOTES.

Fluorite in Quartz-Porphyry from Sleemanabad, Jubbulpore District.

IN many parts of the world, one of the commonest minerals in metalliferous veins is fluor-spar or fluorite. In India, however, this mineral may almost be regarded as a rarity, as it has been reported from but few localities and from none of these in any quantity. Consequently, any fresh occurrence of fluorite possesses considerable interest. At Sleemanábád, in the Jubbulpore district, Central Provinces, is a series of parallel metalliferous veins striking in a north-north-west direction through dolomitic limestones of Archæan age. In opening up these deposits, the following minerals have, up to the present, been found:—chalcopyrite, tetrahedrite, galena, pyrite and barite with malachite, azurite, chrysocolla and oxides of iron and manganese as gossan products.

Mr. A. Whyte of Rániganj recently brought to the Geological Survey Office a rock (17·782) obtained from an opening about 100 yards north of what is locally known as the "Eric pit." This specimen shows slickensiding striations, and is a horny-looking rock of yellowish colour. It can easily be scratched with a knife, and contains abundant small scattered specks of deep purple fluorite, averaging $\frac{1}{16}$ in., although ranging at times up to $\frac{1}{4}$ in across and tending to be idiomorphic with squarish outlines. There are also a few scattered glassy quartz phenocrysts usually $\frac{1}{8}$ to $\frac{1}{4}$ in. in diameter, and commonly more or less rounded, but sometimes with hexagonal or polygonal outlines. The rock, in fact, would be described from the hand-specimen as a "quartz-felsite" or quartz-porphyry.

In thin sections under the microscope the ground-mass of the rock is seen to consist of micro-crystalline quartz with extremely abundant tiny sericite (secondary muscovite) laths traversing it in all directions and consequently, as a rule, obscuring the boundaries between the quartz grains. When seen, however, these boundaries are usually simple and fairly well-defined, either straight or curved, and not interlocking. The quartz phenocrysts also have their outlines quite firm and decided as seen under a 1-inch objective, but under higher powers the tiny sericite laths of the ground-mass are seen to project into them.

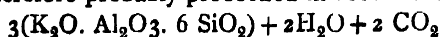
The microscope, therefore, shows this rock to be a peculiar type of quartz-porphyry, in which the ground-mass is composed entirely of micro-crystalline quartz and sericite.

Though the relation of this fluorite-bearing quartz-porphyry to the surrounding rocks has not yet become evident in the workings, nevertheless

Mr. Whyte has found at the same locality two distinct dykes of similar rock (17·781 and 17·783), with a strike roughly parallel to that of the ore-veins, but containing no fluorite. The ground-mass of these dyke-rocks is similar to that of the fluorite-bearing rock, but one of them (17·783) also contains some creamy-pink felspar phenocrysts. This felspar, which is probably orthoclase, is seen under the microscope to be giving place to secondary quartz, muscovite (sericite) and calcite, and in some places completely changed to material very similar to that of the ground-mass.

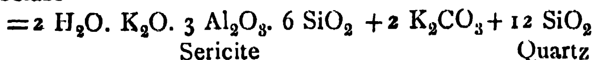
The specific gravity of a piece of the fluorite-bearing rock was found to be 2·745, and of pieces from the two dykes to range between 2·675 when containing felspar and 2·74 with felspar practically absent. The similarity in composition, structure and specific gravity of the two dykes and of the fluorite-bearing rock shows that the latter is probably also a dyke, and that the three are, doubtless, contemporaneous.

I am inclined to regard this rock as an altered quartz-porphyry, the original ground-mass of which has been so changed that its felspar has suffered the transformation actually observed in the felspar phenocrysts of 17·783, *i.e.*, into sericite and quartz. The quartz-phenocrysts, as was to be expected, have remained practically unaffected except, as mentioned above, on their edges, although inclusions of the ground-mass in the quartz have suffered the usual change. A portion of one of the fluorite-free rocks (17·783), of specific gravity 2·74, containing no felspar and but few quartz-phenocrysts, was found by Mr. Blyth to contain 74·19% SiO_2. This result is quite normal for a quartz-porphyry, and hence furnishes no evidence of either addition or removal of silica. The change of orthoclase to sericite and quartz has therefore probably proceeded in accordance with the following equation :—



$$3(K_2O.\ Al_2O_3.\ 6\ SiO_2) + 2H_2O + 2\ CO_2$$

Orthoclase



$$= 2\ H_2O.\ K_2O.\ 3\ Al_2O_3.\ 6\ SiO_2 + 2\ K_2CO_3 + 12\ SiO_2$$

Sericite — Quartz

The only agent necessary to produce this reaction is water containing carbon dioxide, and in such a change, if the free SiO_2 separate as quartz, the aggregate volume of the two secondary, minerals will, as noticed by W. Lindgren,[1] show a reduction of 13% from the volume of the orthoclase. As the original quartz still remains in the rock, the total percentage reduction in volume will be less than that amount, but still sufficient to account for the fact that the specific gravities of these rocks are somewhat higher than in normal quartz-porphyries.

Under the microscope the fluorite sometimes shows idiomorphic squarish outlines; but in the majority of cases, the purple spots of the hand-specimen resolve themselves into areas composed of the quartz-sericite ground-

[1] "Metasomatic Processes in Fissure-Veins." Trans. Amer. Inst. Min. Eng., XXX, p. 608 (1900).

mass, with very abundant patches of fluorite up to 0·2 mm. across, which apparently occupy interstices or cavities in this ground-mass, the quartz and sericite of which sometimes show idiomorphic terminations projecting into the fluorite. There are also, in places in the latter, some long minute, presumably colourless, needles. In such areas the colour is a fairly uniform violet, but in the larger more or less idiomorphic individuals the colouring matter is very unevenly distributed, the mineral in one case showing the violet colour so concentrated in spots as to be a deep purple-black with pale violet fluorite around. Another example is nearly colourless with violet spots, whilst almost colourless patches of fluorite are also to be seen. Cleavages are usually only to be observed in these larger fluorite individuals, and sometimes, when the mineral is extinguished under crossed nicols, they stand out as delicate lines of light, indicating the formation along them of some secondary anisotropic mineral. The very low index of refraction of the fluorite is also noticeable, so that it appears depressed below the level of the surrounding quartz.

As regards the distribution of the fluorite, it certainly seems to be more abundant close to the quartz-phenocrysts. In fact, in one case, a tongue of the ground-mass containing abundance of fluorite is seen projecting into a quartz-phenocryst, with some of the fluorite protruding into the quartz, so as to present to it idiomorphic outlines.

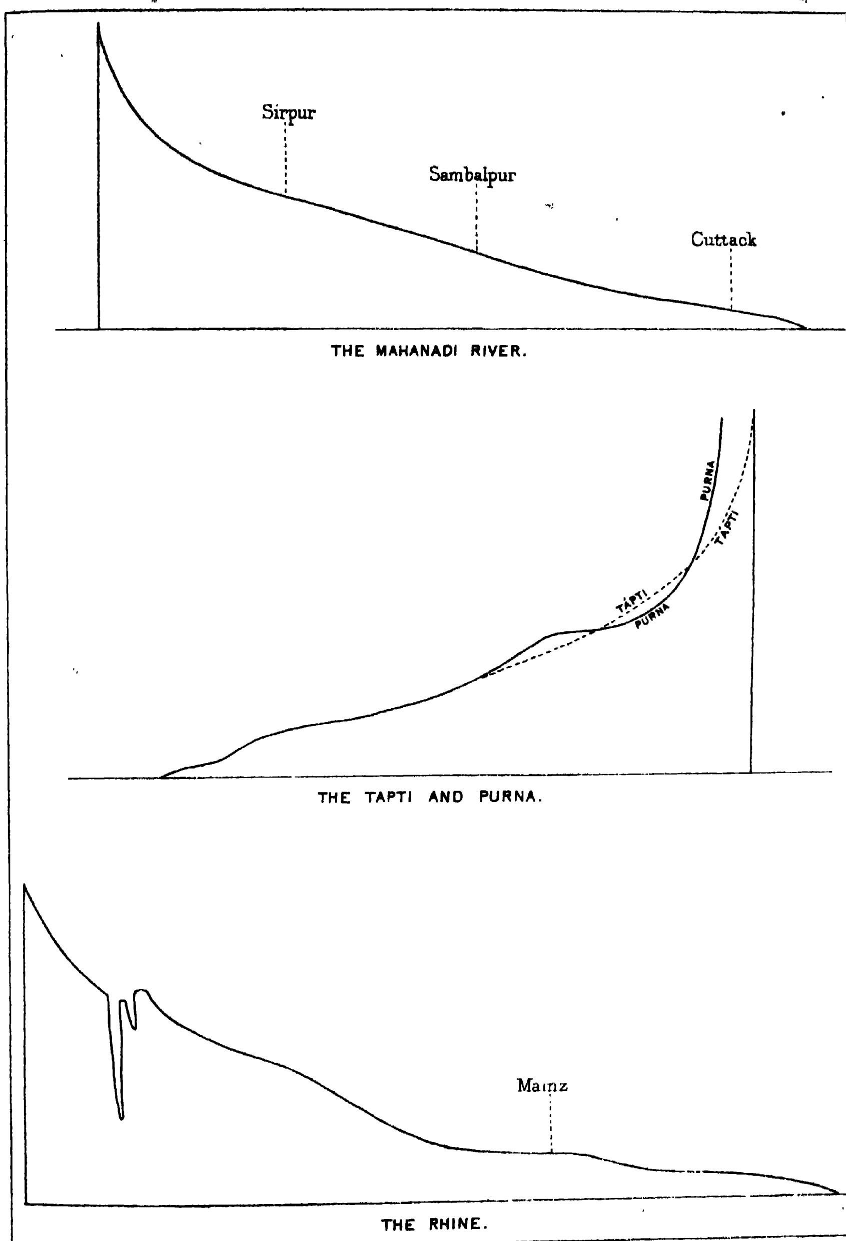
Conclusions.—Although the evidence is not clear, it seems probable, considering the reported parallelism of the quartz-porphyry dykes with the metalliferous veins, that the two are genetically connected. The veins themselves originated in fissures in the dolomite, the formation of these fissures being accompanied by more or less brecciation. The mineralizing solutions then deposited a part of their contents (together with quartz) in the interstices of this breccia and a second portion was introduced into the dolomitic country by the process of metasomatic replacement.

Turning now to the dykes, we see that they must have suffered profound modification, if the sericite-quartz ground-mass be of secondary origin. The introduction of the fluorite into the quartz-porphyry may either have been a concomitant result of this alteration or may have been subsequently effected.

The possible connection between the two sets of phenomena is the following :—The vein-fissures were formed contemporaneously with, or shortly after, the intrusion of the quartz-porphyry, and the mineralization of these veins may be regarded as an after-result of this igneous activity, effected by the passage along the fissures of heated and possibly magmatic waters from below. Whether the alteration of the dykes with introduction of fluorite took place at the same time or not can only for the present be a matter of surmise, but these two sets of chemical processes were probably connected.

[L. L. FERMOR.]

G. I. C. P. O.—No. 788 D. G. Survey—6-2-1906—900.



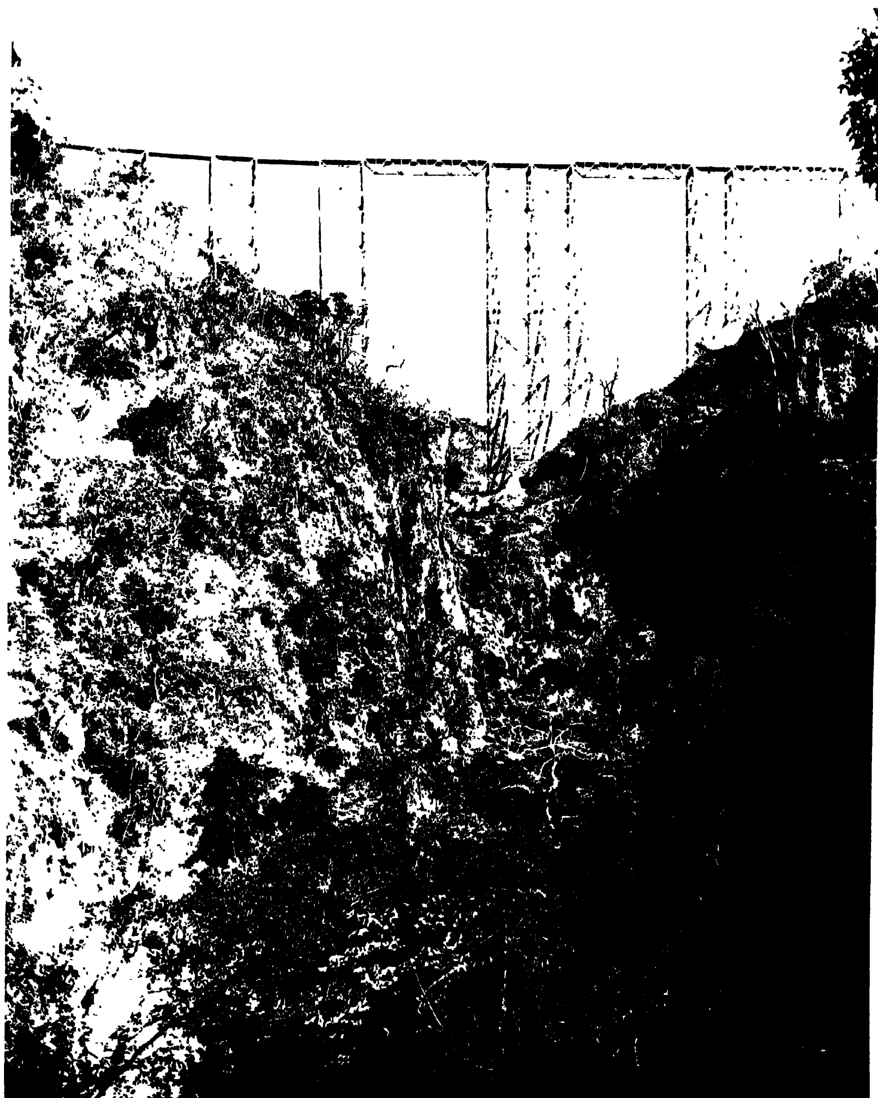
RIVER-PROFILES

Horizontal Scale 1" = 128 Miles. *Vertical Scale 1" = 1000 Feet.*



Photographed by E. Vredenburg

FALLS OF THE NARBADA AT DHARI.



T. D. La Touche, Photo. Bemrose Ltd., Derby. [illegible]

THE NATURAL BRIDGE AND RAILWAY VIADUCT GOKTEIK GORGE

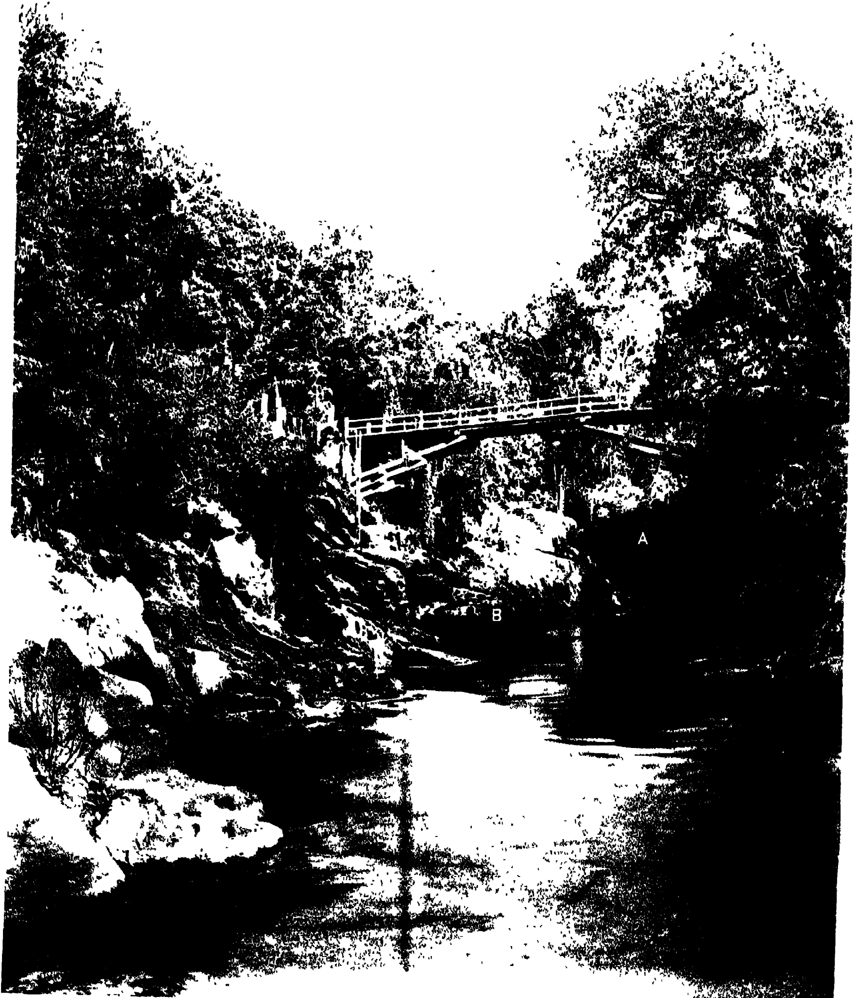
T. D. La Touche.



T. D. La Touche, Photo

Bemrose Ltd., Derby Coll.

CAVERN AT BASE OF NATURAL BRIDGE, GOKTEIK GORGE



T. D. La Touche Photo. *Bemrose Ltd. Derby Ph.*

TRAVERTINE GROWTH ON THE NAMMA RIVER AT HO HKO-NAM-HPAK LUN.

A, B, *Shores of Travertine*

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1906. [March.

GENERAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA FOR THE YEAR 1905. BY T. H. HOLLAND, F.R.S., *Director, Geological Survey of India.*

CONTENTS.

INTRODUCTION.

THE first object of the Department is the preparation of the geological map of India, on which so many scientific and economic questions depend; but, during the progress of the survey, distractions naturally occur in the form of questions arising of more than ordinary interest. Most of this Report is devoted to abstract statements of such results so far as they can be valued at the close of the year; and the rest of it, in accordance with the usual practice, is a bare record of the administrative changes that have occurred during the year.

Head-quarters.

2. The rapid increase in the number of requests from Local Governments, extra-departmental officials and private individuals for advice and information on various questions has necessitated the withdrawal of one of the Superintendents from the field to take charge of the office routine work, thus relieving the Director for the work connected with purely professional cases and the necessary duty of field inspections. Mr. H. H. Hayden, the junior of the three Superintendents, has been in charge of this work at head-quarters during the year, and has proved to be a most suitable selection for the duties which involve such a wide range of questions, geological and geographical.

DIRECTOR'S TOURS.

3. The Director's tours included—

(1) a visit during January to the Sambhar Lake in Rajputana, to discuss, with the Commissioner of Northern India Salt Revenue, the results of the preliminary examination of the salt-bearing silt, and the plans to be adopted for completing the enquiry;

(2) to Bombay with reference to a request made by the Bombay Government for advice about mineral occurrences in the Chota Udepur State;

(3) to the Raipur district, Central Provinces, for the purpose of inspecting the iron-ore deposits near Dullee prospected by Messrs. C. P. Perin and C. M. Weld, on behalf of Messrs. Tata and Sons;

(4) to Upper Burma during February and March for a tour through the oil-fields in the Magwe, Myingyan and Pakôkku districts; to inspect the mud volcanoes of the Minbu district, and the ground surveyed by Messrs. La Touche and Datta in the Northern Shan States;

(5) during April to the Jodhpur State, Rajputana, for an inspection of the marble quarries at Makrána;

(6) during May to attend a Committee at Lahore, to discuss the question of selecting a head-quarters' station for the Kángra district, and later to Dharmsala to inspect the results of the earthquake of April 4th;

(7) during November to Ajmer to consult the Agent to the Governor-General with reference to water-supply questions and the proposed survey of the Rajputana States; to the Kishengarh and Jodhpur States with reference to the development of the marble quarries; and

(8) at the end of December the Director attended the Industrial Congress held at Benares.

DISPOSITION LIST.

4. During the period under report the officers of the Department were employed as follows:—

Superintendents.

Mr. Tom D. La Touche	Returned from the Northern Shan States, Burma, on the 8th May 1905. Deputed to Burma for the mapping of the unsurveyed areas east of the Lashio coal-field on the 5th November 1905.
Mr. C. S. Middlemiss	In the field until 9th April 1905. Posted to the Punjab in connection with the Kángra earthquake investigation, and returned to head-quarters on the 8th July 1905. Deputed to Central India and Rajputana in charge of Survey Party, and left for the field on the 6th November 1905.
Mr. H. H. Hayden	At head-quarters in charge of office throughout the period.

Deputy Superintendents.

Mr. P. N. Datta . .	Returned from the Central Provinces on the 28th April 1905, and deputed to the same area on the 15th October 1905, after arranging the geological specimens in the Nagpur Museum.
Mr. E. Vredenburg . .	At head-quarters as Curator up to 19th March 1905. Deputed to Panna State on the 20th March, and returned to head-quarters on the 30th April 1905. Posted to Baluchistan, and left for the field on the 26th September 1905.
Mr. L. L. Fermor . .	Returned to head-quarters on the 8th March 1905 and took over the duties of Curator on the 18th idem.
Mr. Guy E. Pilgrim .	Returned from the Persian Gulf on the 21st June 1905. On privilege leave from the 16th October to 25th October 1905. At head-quarters as Palæontologist.
Mr. G. H. Tipper . .	Returned to head-quarters, from duty with the Andaman Exploration Party, 8th June 1905. Posted to Baluchistan on the 17th September 1905.

Assistant Superintendents.

Mr. H. Walker .	Returned to head-quarters from the field on the 7th May 1905, and posted to Mr. Middlemiss's party on the 5th November 1905.
Mr. E. H. Pascoe . .	Joined the Department on the 2nd March 1905. Posted to the Punjab in connection with the Kángra earthquake investigation on the 8th April, and returned to head-quarters on the 11th May 1905. Deputed to Burma in connection with the oil industry, and left for the field on the 17th September 1905.

Mr. K. A. K. Hallowes .	Joined the Department on the 14th April 1905. Posted to the United Provinces in connection with the Kángra earthquake investigation on the 19th April 1905, and returned to head-quarters on the 3rd July 1905. Posted to Chota Nagpur in charge of boring operations on the 13th November 1905.
Mr. G. de P. Cotter .	Joined the Department on the 14th April 1905. Posted to Mr. Middlemiss's Survey party, and left for the field on the 6th November 1905.
Mr. J. Coggin Brown .	Joined the Department on the 19th November 1905.

Mining Specialists.

Mr. R. R. Simpson . .	Returned from Burma on the 3rd April 1905. Posted to the United Provinces in connection with the Kángra earthquake investigation on the 8th idem, and returned to head-quarters on the 7th May 1905. Deputed to the Nága Hills, Assam, and left for the field on the 8th November 1905.
Mr. J. M. Maclaren . .	Returned to head-quarters on the 5th June 1905. On privilege leave from 5th July to 2nd October 1905. Deputed to Burma for an examination of the river gravels, and left for the field on the 14th October 1905.

Sub-Assistants.

S. Sethu Rama Rau .	Returned from the field on the 8th May 1905. Posted to Mr. Middlemiss's party, and left head-quarters on the 4th November 1905.
M. Vinayak Rao . . .	Returned to head-quarters on the 5th June 1905. Deputed to Sind for investigation of the Indus river, and left on the 30th October 1905 for Kotri.

Assistant Curator.

Mr. T. R. Blyth . .	On duty at head-quarters throughout the period.

ADMINISTRATIVE CHANGES.

New Appointments. 5. The following officers joined the Department during the period under report :—

Mr. E. H. Pascoe, M.A., B.Sc., who joined the service on the 2nd March 1905;

Mr. K. A. K. Hallowes, B A., A.R.S.M., F.G.S., who joined on the 14th April 1905;

Mr. G. deP. Cotter, B.A., who joined on the 14th April 1905; and

Mr. J. Coggin Brown, B.Sc., who joined the service on the 19th November 1905.

Promotion. Mr. G. H. Tipper was appointed to be Deputy Superintendent with effect from the 6th December 1905.

Leave. Mr. J. M. Maclaren, Mining Specialist, was granted privilege leave from the 6th July 1905 to the 2nd October 1905; Mr. G. E. Pilgrim, Deputy Superintendent, was granted privilege leave from the 16th to the 25th October 1905; Mr. H. H. Hayden, Superintendent, was granted special privilege leave from the 16th October 1905 to the 3rd November 1905.

PUBLICATIONS.

Records. 6. The four parts forming volume XXXII of the *Records* were published during the year, containing the following papers and notes :—

Review of Mineral Production of India during the years 1898 to 1903, by T. H. Holland, F.R.S.

General Report of the Geological Survey of India for the period April 1903 to December 1904, by T. H. Holland, F.R.S.

Preliminary Note on the Geology of the Provinces of Tsang and Ü in Tibet, by H. H. Hayden, B.A., B.E., F.G.S.

The occurrence of Bauxite in India, by T. H. Holland, F.R.S.

Notes on an Anthracolithic Fauna from the mouth of the Subansiri Gorge, Assam, by Professor C. Diener, Ph.D.

On the occurrence of *Elephas antiquus* (*namadicus*) in the Godávari alluvium, with remarks on the species, its distribution, and the age of the associated Indian deposits, by Guy E. Pilgrim, B.Sc.

The Triassic Fauna of the Tropites-Limestone of Byans, by Professor C. Diener, Ph.D.

On the occurrence of Amblygonite in Kashmir, by F. R. Mallet, late Superintendent, Geological Survey of India.

Obituary Notices of H. B. Medlicott and W. T. Blanford.

Preliminary Account of the Kángra Earthquake of 4th April 1905, by C. S. Middlemiss, B.A., F.G.S.

Miscellaneous Notes on :—

Imports and Exports of Mineral Products during 1904.

The Kángra Earthquake of 4th April 1905.

An unusual form of Selenite from the Pachpadra Salt-Source, Jodhpur, Rajputana.

Memoirs.

7. The only Memoir issued during the year was one by Messrs. A. C. Seward and A. S. Woodward on Permo-Carboniferous plants and vertebrates from Kashmir, *Palæontologia Indica*, New Series, volume II, No. 2.

Other papers received for publication are referred to below under the subjects to which they refer.

Mineral Statistics.

8. The Government of India have ordered that in future the returns for mineral production in India are to be summarised and briefly reviewed each year by this Department. The first summary in accordance with these regulations relates to the year 1904, and is published in Part 1 of *Records*, volume XXXIII. This summary includes a list of the numbers and areas of prospecting licenses and mining leases granted in each Province, but in future this list will be supplemented, from information supplied direct by Local Governments, by a statement of the names of those who have been granted concessions, with the dates and periods of the licenses held.

MUSEUM AND LABORATORY.

Curator and Assistant Curator.

9. Mr. L. Leigh Fermor took over charge of the Museum and Laboratory from Mr. E. Vredenburg on the 17th March, and confirms the reports of his predecessors in testifying to the valuable help

rendered in every section of the Curator's work by Mr. T. R. Blyth, the Assistant Curator.

Determinative work.

10. There has been a further increase in the number of specimens referred to the Curator for determination and analysis by extra-departmental officials. During the year 1905 the number of specimens thus examined in the Laboratory amounted to 782 against 524 for the preceding calendar year. Such an addition to the Curator's duties would have been beyond his capacity, but for the assistance given by the other officers during the recess season. Naturally most of the specimens received for determination prove to be of little interest; but it is dangerous to discourage this section of the work, on account of the fact that amongst them occasionally occur "finds" of considerable scientific or economic value. The chief disadvantage of working this section of the Department under high pressure is due to the fact that the officers in the Laboratory have not time sufficient to follow up and develope such interesting cases to the stage necessary to turn the results to practical account.

Apprentices.

11. The facilities granted for the training of students have been continued during the year, and an apprentice sent by the Director of Agriculture, United Provinces, has commenced a period of training at head-quarters. The limited accommodation at head-quarters makes it impossible to entertain more than two or three such apprentices, but the work is obviously one that might be extended with advantage to the Departments of Agriculture and Forests in which subordinate officials have frequent opportunities of coming into contact with geological problems, and to whom a knowledge of mineralogy should be of value to Local Governments. If the satisfactory results so far obtained from this system are confirmed by further experience, it will be necessary to make proposals for an increase of Laboratory accommodation.

Meteorites.

12. During the past year five meteorites, all stones or aerolites, have been added to the collection. One of these, Mount Browne, was obtained by exchange, while the other four fell in India One of these, weighing 32·4 lbs. and evidently but a portion of a much larger aerolite, was seen to fall near *Karkh* (27°45'—67°15'), Jhalawan, Baluchistan, on the 27th of April 1905; the second, weighing 1000·6 grammes and largely covered with crust, is one of two stones seen to fall as recently as the 29th of

October 1905 at *Bholghati*, Deoli pargana, Mayurbhanj State; the third, presented by the Rev. Father Francotte, S.J., is a small fragment, weighing only 0·792 grammes, of a fall of two stones at a village some five miles from *Delhi* near the Kutb Minar on the 18th of October 1897; the fourth, weighing 1,078·8 grammes, fell in August or September 1878 about 14 miles west of *Basti*, Basti district, United Provinces, and has been named the *Haraiya* meteorite after the village situated in the position indicated (26°48′—82°31′); this aerolite is almost perfect and shows well-marked furrows radiating from a point on one side of the stone, doubtless cut by the air in the fused exterior of the meteorite during its rapid passage through the atmosphere. With these additions the number of meteoric falls represented in our collection has reached a total of 388, comprising 148 siderites (and siderolites) and 240 aerolites, of which totals 2 and 64 respectively are Indian.

Museum.

13. A satisfactory amount of work has been done in the Museum during the past year. Besides replacing old labels and generally cleaning up the cases and specimens in the Economic Mineral collection, a start has been made in replacing the name labels standing at the head of each mineral species in the mineral collection with labels on which, in addition to the name, both chemical formula and crystal-system are shown. Considerable progress has also been made in the re-arrangement of the Productus-Limestone fossils in the Palæontogical Gallery. Messrs. D. Waldie & Co. have presented to the Museum glass-ware of an estimated value of Rs. 1,372-7-0.

Assistance to Provincial Museums.

14. The Department has undertaken to assist Provincial Museums in classifying their geological collections. During the past year Mr. Hayden made a preliminary examination of the contents of the Nagpur Museum, and Mr. Datta subsequently went through the collections in detail, forwarding to Calcutta for determination all specimens that could not be identified on the spot. In consultation with the Trustees, it was arranged that the Geological Survey should undertake the work of classifying and determining the specimens, as well as of contributing suitable duplicates separated from the material collected by our officers when in the field, on the understanding that all type-specimens, or specimens of historic value, should be transferred to Calcutta. In this way the more valuable types will be accumulated in the Calcutta Museum, which aims especially at serving the functions

of a central reference Museum for India. At the same time, the Provincial Museum will be supplied with duplicates, which will serve all the purposes of a purely educational collection. Similar work has now been undertaken with regard to the Lahore Museum, from which a large collection of material has been obtained for determination.

LIBRARY.

15. The additions to the Library during the period 1st January 1905 to 31st December 1905 amounted to 2,638 volumes. Of the books received this year 1,117 were acquired by purchase and 1,521 by presentation.

PALÆONTOLOGY.

Palæontologist.

16. Mr. Guy E. Pilgrim has been Palæontologist throughout the year. His work at head-quarters was interrupted by a journey to the Persian Gulf, which resulted in the collection of more material than could be worked out during the following recess. As part of his determinative work, Mr. Pilgrim examined a number of fossil fish and reptilian teeth with chelonian and mammalian remains and silicified wood, obtained by Messrs. Finlay, Fleming & Co. in gravel at 220 feet below the surface from a boring near Syriam, on the Pegu river below Rangoon. Mr. Pilgrim concludes that the specimens were probably *in situ,* thus indicating the extension so far southward of the Irrawadi series, in which such fossils are known to occur in Upper Burma.

Lower Palæozoic, Northern Shan States.

17. Mr. F. R. Cowper Reed has completed a memoir on the fossils of Lower Palæozoic age from the Northern Shan States, Dr. F. A. Bather having assisted with descriptions of the cystidean remains, and Miss G. L. Elles by determinations of the graptolites. The collections obtained from the Naungkangyi beds present in general strong affinities with the Lower Ordovician beds of Northern Europe, particularly of the Russian Baltic Provinces, the only anomalous form being the cystidean *Aristocystis*, which is a typically Bohemian and South European genus.

18. The fossil evidence from the Nyaungbaw beds is insufficient to permit of precise correlation with the European stratigraphical scale, though Mr. LaTouche is disposed to regard these beds as correspond-

ing to the top of the Ordovician. The principal form of interest is the fossil which has been frequently referred to as *Echinosphærites*, and was described by Dr. Noetling as *E. Kingi* in 1890.[1] Mr. Reed has identified the form with Hall's genus *Camarocrinus*, a form whose true morphological nature and precise zoological position are unsettled. Only one species has been recognised, and this, *C. quadrilobatus*, is regarded as new, but is nearly related to *C. Ulrichi*, Schuchert, from the lower part of the Helderbergian of the United States.

19. The Namhsim sandstones and Zebingyi beds have been referred to the Silurian (Gothlandian) by Mr. LaTouche, and the fossil collections examined by Mr. Reed confirm this conclusion, although the Zebingyi beds include forms like *Tentaculites elegans* characteristic of the South European Lower Devonian, associated with species of *Monograptus* known in the Upper Wenlock. There is a marked contrast between the two formations, in lithological as well as in palæontological characters: the arenaceous Namhsim series, with its abundant brachiopods, clearly agrees with the Wenlock of Northern and Western Europe, whilst the fossils in the argillaceous and calcareous Zebingyi series have their nearest relatives in the South European province, including forms ranging from Wenlock to Lower Devonian in an association which might possibly be due to migration, but which could not be accepted as such without more definite proof (than is obtainable in a country so marked by superficial products) that the apparent is actually the real order of succession amongst the beds.

Triassic: Baluchistan.

20. Professor C. Diener of Vienna has described the Triassic fossils collected by Mr. E. Vredenburg in a series of shales occurring in the Pishin district of Baluchistan, where, on account of their previously supposed unfossiliferous character, they were grouped with the associated Khojak shales of Tertiary age. In a paper published in volume XXXI of the *Records*, Mr. Vredenburg described the occurrence of these fossils, amongst which he identified a species of *Monotis* allied to *M. salinaria*, Schloth., and a species of the ammonite *Halorites* of the group *Catenati continui*. On account of the presence of these two forms, the beds were correlated with the *Monotis*-beds of Spiti, and the alaunic (middle noric) sub-stage of the Alpine Upper Trias. A critical examination of all the fossils collected

[1] *Rec. Geol. Surv. Ind.*, XXIII, 78.

now enables Professor Diener to confirm this conclusion in so far as the correlation with the Alpine noric stage is concerned, but the scanty, and not always determinable, material prevents a more precise identification with horizons on the European scale. Professor Diener's paper will be published in *Records*, volume XXXIV.

Triassic: Central Himalayas.

21. Professor C. Diener has also made a critical examination of the fossils collected in 1900 by the late A. von Krafft from the *Halorites*-limestone of the Bambanag cliff above the Girthi Valley in the Central Himalayas of Kumaon. The occurrence of a rich fauna in these rocks was detected by the expedition in which Messrs. Diener, Griesbach and Middlemiss took part in 1892, and these Upper Triassic fossils were described by Professor E. von Mojsisovics,[1] who came to the conclusion that the limestone named *Halorites*-limestone, from the abundance of this genus, could be correlated with the lower noric (lacic) stage of the Alpine Trias, although he noticed also that a small number of types were closely related to species of middle noric (alaunic) age. Amongst the specimens collected by von Krafft, Professor Diener has detected and described some forms not previously collected from this locality, a few being new species, and one a new genus, the previous stratigraphical conclusions being in general confirmed. Professor Diener's paper will be published in *Records*, volume XXXIV.

22. In part 3 of volume XXXII of the *Records*, Professor Diener has published a summary of the results of his study of fossils from the *Tropites*-limestone of Byans in the Central Himalayas of Kumaon. The full results form the subject of an elaborate memoir now in the press as a part of the *Palæontologia Indica.* The rich collection of fossils studied was obtained by the Geological Survey officers from a limestone bed only three feet thick, which, on account of the preponderance of the ammonite genus *Tropites*, is known commonly as the *Tropites*-limestone. The most interesting result of Professor Diener's study is the determination within this thin bed of forms belonging to both the carnic and noric faunas of the Alpine Trias; but instead of their being, as one would expect, mere transition forms with a preponderance of types belonging to the uppermost carnic and lowermost noric, the fossils are a mixture of the four sub-stages, julic, tuvalic, lacic and alaunic. Professor Diener ascribes this mixture to deficiency of sedimentation in the Kumaon area, not to the fact that the forms charac-

[1] *Pal. Ind.*, Series XV, vol. III, Part I.

teristic of well separated stages elsewhere lived together in this area: the 3-foot bed of *Tropites*-limestone in Byans is thus equivalent to the much greater thicknesses of carnic and noric strata further west in Spiti, and this conclusion is in agreement with the general thinning of the Trias in passing south-eastwards from Spiti.

Nummulitic formations.

23. Mr. E. Vredenburg, during the recess season, continued his study of our Tertiary *Foraminifera*, and has produced an exhaustive descriptive memoir for publication in the *Palæontologia Indica.* The Nummulitic fauna is a very rich one: all the most important types are represented with the exception of *N. irregularis*, *N. Brongniarti* and *N. contorta*, whilst several new varieties and one new species have been distinguished. It is noticed, also, that the individuals in India attain in general larger dimensions than those belonging to the same species in Europe.

In every instance both the megaspheric and the microspheric forms of each species are present; but the relative proportions of the two forms vary considerably, and this variation is not always due to sorting by currents; for in the case of the small *Assilina miscella* of the Ranikot series, the megaspheric form is much more abundant than the microspheric one, although occurring in a coral limestone with innumerable large specimens of *N. planulata*, and crowds of fossils of every description, amongst which there is no indication of the action of currents. In the case of the *Alveolina*-limestone, also, constituting the upper Laki, which contains innumerable large specimens of *N. atacica* and scarcely any of *N. globulus*, the rock is crowded with *Alveolinæ*, many of which are quite as small as the last-named nummulite.

The curious reversal in the direction of spiral growth noticed by d'Archiac and Haime and other authors has been detected amongst Indian individuals of the species, *N. Carteri*, *N. obtusa*, *N. aturica* and *N. intermedia*, whilst the effects of the parasitic organism which sometimes destroys the septa throughout a portion of the spire has been noticed to be more pronounced in some localities than in others, for instance, at Sukkur in Sind, where the majority of the specimens of all species are thus attacked. Some of the specimens from Cutch have their chambers filled with bitumen, and as the bituminous material does not impregnate the surrounding rock it appears to be the result of the metamorphism *in situ* of the original sarcode.

PETROLOGY.

The Deccan Traps: Pavagad Hill.

24. The remarkable outlier of the Deccan Trap formation forming the isolated and striking mass known as Pávágad (Powagarh) Hill, in the Panch Mahâls district, Bombay, previously examined and described by the late Dr. W. T. Blanford,[1] was hastily examined by Mr. Fermor during his tour through the manganese-bearing localities. It was found to be of great interest owing to the fact that it is composed of interbedded basalts and rhyolites, with rhyolite breccias and ashes. A comparison with the felsites and trachy-felsites referred to by F. Fedden as interbedded with the basalts in the Káthiáwár area showed that they also are rhyolites possessing the essential and peculiar features of those in the Pávágad hill.[2]

It will require more detailed field-work than that possible at the time of Mr. Fermor's visit to demonstrate that the basalts and rhyolites of Pávágad are genetically related to one another, but all observations point to this conclusion—those made in the field as well as the microscopic characters. The only other hypothesis with regard to the origin of the rhyolites is suggested by their superficial similarity to the acid rocks of pre-Vindhyan age known as the Maláni series; but if the rhyolites were of Maláni age it would be necessary to admit the unlikely regular intrusion of basaltic sheets between the beds of much older rock.

The association of acid and basic extremes of this kind has been so frequently demonstrated in other parts of the world that it is more natural to regard this complex in the Pávágad hill as the products of differentiation in the magma which gave rise to the Deccan Trap. Cases of the kind elsewhere have been referred to in a paper explaining the frequent, almost constant, occurrence of acid micropegmatite in the diabasic (augite-diorite) dyke-rocks of South India.[3] In Baluchistan, also, Mr. E. Vredenburg has found granophyres associated with gabbros of Lower Tertiary age, and it seems not improbable that such rocks are relatives of the great Deccan Trap outflows. It is interesting to find that these acid rocks occur on the north-west border of the Deccan Trap mass, for further west, in the Persian Gulf region,

[1] *Mem. Geol. Surv. Ind.*, VI, 343 (1869).
[2] *Mem. Geol. Surv. Ind.*, XXI, 96—99 (1884).
[3] Holland: *Quart. Journ. Geol. Soc.*, LIII, 405 (1897).

Mr. G. E. Pilgrim[1] has described the occurrence of rhyolitic lavas in the Hormuz series, which is of about the same age as the Deccan Trap of India. It thus appears that the acid products of the magma that gave rise to the Deccan basaltic flows have been brought to the surface in the western and north-western areas; but they may nevertheless lie concealed in Peninsular India on account of the perfect tectonic quiescence prevailing in this area since Lower Tertiary times. The whole assemblage recalls the well-known complexes of Tertiary basic and acid igneous rocks of the Western Isles of Scotland.

Borderland problems are always the most interesting amongst scientific investigations, whether marked by the changes amongst genetically related bodies that indicate the complex phenomena grouped under evolution, or whether the result of contact metamorphism between two unrelated bodies distinct in origin. It is in the Káthiáwár and Cutch areas that Mr. J. F. Blake found such interesting structural features where the Deccan Trap series come into contact with the sedimentary rocks, and it was in this area that Dr. J. W. Evans discovered the first of the nepheline-bearing rocks in India.[2] Dr. Evans has not yet completed the examination of the materials he collected in the Junagádh State some ten years ago, but I understand that he hopes soon to publish his results, and we shall then be free to take up the area in detail, using his preliminary observations as a basis for systematic work.

Archæan: Chhindwara district.

25. Mr. L. L. Fermor has made a petrological study of the rocks associated with the manganese-ore deposits of the Sausar tahsil in the Chhindwára district, Central Provinces. The rocks examined include, besides the Archæan gneisses and schists with which the ore-bodies are directly associated, the adjoining Deccan Trap flows and Lameta beds. The Archæan crystalline rocks described include various forms of granites, granulites, gneisses, schists, quartzites, calciphyres, cipolins and crystalline limestones besides the manganese-ores.

The evidence obtained with regard to the calciphyres and crystalline limestones is held to justify the deduction that they have been

[1] *Vide infra*, p. 113.

[2] Monchiquite from Mount Girnar (Junagádh). *Quart. Journ. Geol. Soc.*, LVII, 38—54 (1901).

derived from pyroxenic and felspathic gneisses by metasomatic chemical changes, thus confirming Professor Judd's similar views with regard to crystalline limestones of this class in the Burma Ruby Mines district. The study of these crystalline limestones, which are often dolomitic, has led Mr. Fermor to investigate the reliability of recognised tests for distinguishing between the closely similar crystals of dolomite and calcite in microscopic sections. He finds that, by relying on the staining tests with Lemberg's solution, the other criteria are never constant, and that the majority of results are even opposed to the commonly recognised characters for these minerals, though Mr. Fermor's results agree in general with those of Lacroix for the crystalline limestones of Ceylon.

Short descriptions are given of eleven deposits of manganese-ore occurring in the area, but these and the new forms of manganiferous minerals will be described in detail in a memoir, now in course of preparation, on all the known manganese-ore deposits of India. Mr. P. N. Datta made a survey of this area some ten years ago, and his field notes with geological map will be published with Mr. Fermor's paper on the petrology.

PHYSICAL GEOLOGY.

Pleistocene movement in the Peninsula.

26. The discovery of pleistocene vertebrate fossils in the alluvium of the Upper Godávari valley, referred to in the last General Report, has led to a study by Mr. Vredenburg of the distribution of these pleistocene gravels in the river-valleys of the Peninsula, and consequently of the changes of level they indicate. One of the most interesting of these results is the evidence of a warping of the Peninsular mass along an anticlinal axis running N.N.E.—S.S.W. through Buldána in Berar and near Sehore in Bhopál. The pleistocene deposits of the Upper Godávari, which flows eastwards, and the lower Tápti, which flows westwards, lie to the west of this axis, whilst those of the Purna, which joins the Tápti, and the extensive deposits in the Narbáda lie to the east of the hypothetical axis. Whilst there is no proof that lakes were formed, the alteration in the slopes of the valleys, due to this bending of the crust, changed the erosive tracts of the rivers into areas of temporary deposition, with the resulting accumulations of alluvium which have since been eroded but not entirely removed.

Mr. Vredenburg's paper is published in Part 1 of the current volume of the *Records*.

Nam-tu river, Northern Shan States.

27. During the course of his survey work in the Northern Shan States Mr. LaTouche made a study of the recent changes in the course of the Nam-tu river, which formerly ran in a south-west direction from about where the Tati ferry is now situated to near Hsipaw; the present course is south-eastward from Tati into the Namma valley, and evidences of the deserted course are still visible.

Gokteik Natural Bridge.

28. Mr. LaTouche has also made a study of the remarkable travertine terraces that form such a characteristic feature of the rivers in this area, and has described in detail the natural bridge of calcareous tufa across the Chaungzong river near Gokteik over which the Maymyo-Lashio Railway line has been laid. These subjects are discussed in two separate papers published in Part 1 of the current volume (XXXIII) of the *Records*.

SEISMOLOGY.

Kangra Earthquake of April 4th, 1905.

29. The circumstance of most general public interest during the year was naturally the destructive earthquake that devastated the Kángra valley on the 4th April. Owing to the interruption of communications, it was not until the 6th of April that the full significance and magnitude of the shock became generally known in India, and steps could be taken for the proper scientific investigation of it. By that date, however, telegraphic warnings were issued by the Director of the Geological Survey to all District Engineers, Meteorological Observers, Telegraph Masters, Railway officials and others through their respective Departments, to record in writing the exact time and other details of the shock. These were followed by letters sent to the principal newspapers inviting volunteers all over India to answer a formulated set of questions, and to assist in other ways by furnishing data as to the local effects. Question forms were also despatched to all the Provinces, and, through the Political Officers, to the Native States. For the more critical study of the effects four officers of the Geological Survey were deputed at once to the affected areas. Mr. C. S. Middlemiss, who was at the time in charge of the Central Indian party, within 24 hours

after receiving orders, had made the necessary preparations and had started for a tour through the Kángra district including the Kulu tahsil; Mr. E. H. Pascoe examined the large towns on the plains in the Punjab; Mr. R. R. Simpson investigated the area including Mussoorie, Dehra Dún, Hardwar, Sahâranpur and Rurki, being assisted in the Mussoorie area by Mr. K. A. K. Hallowes. Mr. C. S. Middlemiss was entrusted with the compilation of results, and has already published a preliminary summary of results in volume XXXII of the *Records*. The full memoir is now in course of preparation. To the promptness with which Mr. Middlemiss prepared for the work and the energy with which he traversed the area in which all the ordinary means of transport and accommodation had been destroyed, I am indebted for the very complete and precise data that have been obtained from the most seriously affected part of the ground.

30. In consequence of the fact that the more violent phases of the earthquake began with little warning at an early hour in the morning, when many people were still asleep, the destruction to life was enormous in the epicentral tract. That preliminary tremors occurred is, however, clear from the accounts of survivors in the Kángra valley and neighbourhood, as well as at more distant points. In some cases in Dharmsála these preliminary warnings are stated to have enabled persons to leave their dwellings just in time, and although 135 perished in the Gurkha barracks, such tremors are nevertheless implied by the fact that scarcely any of them were found killed in their beds. In Dehra Dún, also, minor preliminary vibrations are recorded which enabled those who were awake to reach the door. In Mussoorie, according to an eyewitness, preliminary tremors lasted from 15 to 20 seconds; and the same were noticed in Landour by several people. In Lahore preliminary shocks with intervals appear to have lasted for about 11 seconds before the arrival of the main shock.

Besides the almost complete destruction of buildings in the Kángra area, the earthquake accomplished very great damage and caused considerable loss of life in the hilly tracts of Mandi State and Kulu; did serious damage to Dehra Dún, Mussoorie, Chakráta and other towns in the vicinity; and slight damage to the large towns of Lahore, Amritsar, Jullundur, Sahâranpur and others similarly placed with reference to the centre. Outside these points again, in ever widening closed curves, the effects of the earthquake were felt with continually diminishing intensity, until the limits of its appreciation by the unaided senses coincided roughly with part of an ellipse passing through

the following localities—Quetta, Surat, Ellichpur, False Point and Lákhimpur. This curve, if continued, would pass into the little-known regions of the higher Himalaya and Tibet; and, though no reports have been received from this area, it may be trusted to represent approximately the limit of sensible appreciability in that direction also, and to include a total area of about 1,625,000 square miles. The earthquake must therefore be regarded as a notable one in the seismological history of the present and just concluded centuries, and, inasmuch as 20,000 human beings are estimated to have perished by it, it must also be ranked as one of the most disastrous of modern times.

The distribution of the isoseismal lines, which have been mapped on the evidence of an abundance of independent reports from evenly distributed localities within the affected area, show that there was a main focus aligned parallel to the folded Tertiary rocks, with a steep pitch to the E.S.E. in the Kángra area, and a subsidiary focus parallel to the first under the Tertiary mass in the Dehra Dún area. The depth of the Kángra focus was from about 18 to about 30 miles, with a pitch to the E.S.E. of about 13°. In both areas the geological map shows a noteworthy inbaying of the Sub-Himalayan Tertiary belt, and as the folding and fold-faulting of this tract, which has gone on since early Tertiary times, tends to straighten out the mountain foot into an uniform curve—the southerly convex curve of the Himalayan arc of folds—areas like those of Kángra and Dehra Dún, which show marked irregularities, are in a condition of strain, and are thus favourable to the development of faults, with the earthquakes which often accompany such rock-fractures.

With regard to the surface effects of the earthquake the following points were noticed:—

(1) All the surface valley deposits of alluvium, sand, gravel and boulders appear to have been proportionately more heterogeneously shaken than solid rock.

(2) Of rock, the soft Tertiary sandstones have been thrown into more destructive vibrations than the older and more compacted strata.

(3) Narrow ridges with free ends (spurs) have been very much more shaken than broad areas and the flat hollows between the spurs.

(4) In the case of the more distant vibrations and tremors the great alluvial tracts, and the flat-lying Vindhyans and

Deccan trap with cotton soil, have rendered such weak vibrations apparent, whilst the ancient and steeply dipping Aravalis have resisted the shocks in a very noticeable way. As a consequence there occurs an isolated area round about Udaipur, Dungarpur, Purtábgarh, etc., from which no accounts of any shock have reached us. It is interesting to note that this area was similarly barren of results in the 1897 earthquake, although the shock was recorded both east and west of it.

From observations made with regard to the overturn of pillars near Kángra, the acceleration of the wave particle at that locality was near 13 feet per second per second, with an amplitude of about 9¾ inches. The time of occurrence of the main shock in the Kángra area was 6h. 9m. (Madras time). The larger waves reached the seismographs at Colaba near Bombay and at Alipur near Calcutta in exactly the same time, namely, 480 seconds, and as both places are just 950 miles from the main epicentre, the rate of transmission in both directions was 1·98 miles per second. The record obtained at the Kodaikanal Observatory in South India showed that the same waves took 768 seconds to travel 1,497 miles. Taken along the arc this indicates a speed of 1·95 miles per second. The instruments at Tokio and other places in Japan registered a time which indicated an arcual velocity of 2·05 miles (3·3 kilometres) per second.

Aftershocks.

31. A number of the more prominent aftershocks which occurred at or about the time of the great shock were noted in the earthquake forms that were distributed over Northern India. Others were, and are being, recorded by seismographs in the ordinary routine of meteorological observations. Others, again, during the first few months succeeding the earthquake were reported by the newspapers and by many private individuals, whilst many were noted by Mr. Middlemiss during his tour over the epicentral tracts and by myself in Simla.

But besides these immediate successors of the main shock, it became desirable to institute a regular system of recording the fainter as well as the more violent aftershocks, so long as they continued to be felt at all, in the regions surrounding the main seismic centre. For that purpose a number of volunteer observers have undertaken the task of noting such on specially prepared forms, giving such details as to time, date and approximate intensity as could be furnished without specially installed apparatus.

32. Arrangements have now been sanctioned by Government for the installation of seismological instruments in the Himalayan region. The instruments previously maintained in India were three Milne seismographs at Alipur, Colaba and Kodaikanal, besides simple seismoscopes in Assam and Kashmir. An Omori-Ewing instrument, kindly lent by Professor F. Omori, was erected during June at Simla in the office of the Meteorological Reporter, for the registration of distant and small shocks, but the purchase of new instruments, for the registration at Simla of macroseismic as well as microseismic disturbances, has now been sanctioned by Government.

Seismographs.

ECONOMIC ENQUIRIES.

Building Stone.

33. On account partly of the public interest arising out of the proposal to utilize Indian marble for the Victoria Memorial at Calcutta, there has been a general tendency in India to use the native building and ornamental stone instead of imported material, and the Department has been occupied largely in dealing with enquiries with regard to occurrences of suitable material.

Road-metal for Rangoon.

Towards the close of the field season, Mr. LaTouche was informed by the Chief Engineer, Burma, that all the road-metal used in Rangoon was imported at considerable cost from Bombay, and he was requested to suggest any localities in Burma from which suitable material could be obtained. Being aware that Dr. Oldham had noted the existence of igneous rocks on the banks of the Irrawadi above Mandalay, in the course of his journey up the river in 1855, Mr. LaTouche visited the most southerly of the exposures in company with Mr. Hope, Executive Engineer, Shwebo District, and found that in the hill called Shwemyindé, on the left bank of the Irrawadi, opposite Kyaukmyaung, about 45 miles north of Mandalay, there exists a practically unlimited quantity of basalt of Tertiary age, which would be suitable for road mending. The hill is close to the river, and quarries could be opened in a very convenient position for loading the stone into boats. The quality of the rock, however, is not so good for the purpose as the Deccan Trap imported from Bombay, for a large proportion of it is vesicular, and it is not so dense. It would probably therefore not stand heavy traffic so well as the Bombay rock. The denser portions of the flows would no doubt make very good road-metal, but without

cutting a section through the hill it is impossible to say what proportion these bear to the vesicular variety. The latter is similar to a basalt imported into Rangoon from Mauritius, which is said to be inferior to the Bombay stone, but the Shwemyindé rock is harder than that from Mauritius.

Coal.

Northern Shan States.

34. Mr. R. R. Simpson was occupied during the field season 1904-05 in an examination of the coal-fields in the Northern Shan States. In addition to a re-examination of the previously known fields near Lashio, the terminus of the railway, and Namma, ten miles to the south-east of Lashio, two new fields were found, one near Man-sang (22° 6'; 97° 57') and the other near Man-se-le (22° 40'; 98° 16'). All four fields form isolated basins lying on the prevalent Plateau limestones, and consist of sand, shale and lignitic coal of probably pliocene age.

Lashio coal-field.

35. The last previous examination of the Lashio field was undertaken by Mr. LaTouche in 1902; his work was confined to excavating all the outcrops that could be found, in order to determine the thickness of the seams exposed, and to fixing sites for borings on behalf of the Railway Company. The boundaries of the field were mapped by Mr. P. N. Datta in 1903, whilst, working from the information previously obtained, Mr. Simpson discovered some new outcrops, and made a more thorough examination of those previously known. The results of his work have been amalgamated with those of Mr. LaTouche for publication as a joint paper in the *Records*. On the whole the results in the case of Lashio are not encouraging: the coal-seams all lie below the level of permanent saturation, and as they are interstratified with soft sands and clay-beds mining operations would be difficult and costly. The coal is lignitic, with large quantities of moisture—17 to 20 per cent.—and over 9 per cent. of ash. It burns poorly in the open, with a dull flame and sulphurous odour. When freshly mined it can be obtained in fairly hard and large lumps, but on exposure to the air it rapidly disintegrates into small cubical fragments. The raw fuel is obviously unsuitable for locomotive use; but it may be possible to use it in the form of briquettes, and in this form the fuel would be of service on the railway as far west as Maymyo.

Namma coal-field.

36. The patch of young sands and shales in which the Namma coal occurs, covers an area of about 50 square miles, extending to within 10 miles to the

south-east of Lashio. A small outlier of the coal-bearing rock occurs about 3 miles to the south-west of the main area. In this field, as in all the others of the area, the country is covered with thick jungle, and prospecting operations are further hampered by the coal-basins being lower than the surrounding limestone country; exposures are rare and the ground often water-logged.

Mr. P. N. Datta visited the Namma field at the end of his field season of survey work in this area in 1903, and reported the discovery of a coal-seam 10 to 12 feet thick at a point one mile east of Namma. Mr. Simpson has reported the discovery of numerous other seams, but this area east of Namma seems to include the most promising occurrences. The coal, or rather lignite, is distinctly superior in quality to that of any other field in the Northern Shan States, but in its raw state it would be a distinctly poor fuel, unfit for locomotive use, and would be mined under the usual difficulties due to soft including rocks.

The thick seam east of Namma has been proved by Mr. Simpson for a length of outcrop of 2,400 feet, varying in thickness from about 7 to 17 feet. No determinations have been made beyond the outcrop to estimate the quantity available in this seam. The outcrop is about 19 miles from the nearest point on the Maymyo-Lashio railway line, and 25 miles by existing roads from Lashio railway station, whilst water transport along the Namma river is prohibited by the numerous bars and rapids. To connect the field with the existing railway line would involve some 30 miles of construction, including the bridging of two considerable rivers, the Nam-yau and Nam Pawng. The total cost of mining, briquetting and transport is shown by Mr. Simpson to be well over the present value of the fuel.

Man-sang coal-field.

37. The Man-sang field covers some 14 square miles, with its northern edge about 16 miles S.S.E. of the Namma field. The lignite is similar in character to that of the other fields, and the thickest seam found was no greater than 4½ feet thick. The continuity of the seams is uncertain, the dip variable, and the ground much broken by intrusions of doleritic trap-rocks. The field is separated by about 50 miles of difficult country from the existing railway, and generally, whatever drawbacks mark the two other coal-bearing areas are accentuated in that near Mán-sang.

Man-se-le coal-field.

38. The Man-se-le field is 27 miles E.S.E. of Namma, and is about 13½ square miles in area. There are only one or two seams of possible importance in the field;

the greatest thickness of coal measured was 4 feet; the quality of the fuel agrees generally with that of the other three fields in this area, and the locality is, with present means of communication, inaccessible for development.

Mr. Simpson's detailed report on the Namma, Man-sang and Man-se-le fields will be published in the *Records* with the joint paper on Lashio.

Diamonds.

Panna and adjoining States.

39. Mr. E. Vredenburg made an examination of the Panna diamond-bearing tract during March and April, and has prepared a long report on the mode of occurrence of the gem-stones, and the present state of the industry, with suggestions for improving the methods of mining. The report will be published as a special memoir.

40. The report contains a general account of the geology of the Bundelkhand States, following in the main the lines laid down in 1860 by H. B. Medlicott,[1] the principal change being due to a re-grouping of the beds forming the Lower and Upper Vindhyan systems. Mr. Vredenburg proposes to group together the Lower Vindhyans with the Kaimur and Rewa stages as the Ken series, using the old name Bhander as before for the remaining Upper Vindhyans, but giving it higher rank as a series name, including two stages, the Havelis below and the Betwas above. The revised system has certain advantages in producing a better-balanced sub-division of this remarkable Central Indian formation; but in a conformable succession of unfossiliferous sediments the grouping together of divisions is of less importance than precision in lithological sub-division, which is the only guide towards the identification of horizons in exposures isolated from the type areas. The descriptions of the diamond-bearing areas by various earlier writers, like Buchanan-Hamilton, Pogson, Franklin, Jacquemont, Adam, H. B. Medlicott, Rousselet and Willson, were summarised by V. Ball in the Manual of Geology published in 1883. Mr. Vredenburg, without critically discussing the earlier conclusions, gives an account of the occurrences in the slightly different light of more recent studies of the Vindhyan formations.

[1] *Mem. Geol. Surv. Ind.*, II.

41. In the neighbourhood of Panna the principal diamond-bearing stratum is a thin layer of conglomerate, locally known as "mudda," lying between the Kaimur sandstone and the Rewa shales. The conglomerate is seldom thicker than two feet, and does not form a continuous bed. Further east, in the neighbourhood of Itwa, the diamondiferous conglomerate does not rest directly on the Kaimur sandstone, but is separated from it by a 20—25-foot bed of shale and limestone. Another diamondiferous conglomerate occurs above the Rewa sandstones and under the Bhander shales. This conglomerate differs from that below the Rewa stage in the abundance of pebbles of vein quartz instead of the different varieties of jasper found so commonly in the main diamondiferous conglomerate near Panna.

The diamonds in these conglomerates, like the associated large pebbles of lighter rocks, are derived from older rocks, and the original home of the gem is still unknown, though a precise recognition of the associated pebbles will gradually indicate the direction in which the mother-rock once occurred and possibly still exists. The most characteristic pebbles in the diamondiferous conglomerates are the jasper-pebbles derived from the Bijawar formation and the vein-quartz similar to that traversing the Bundelhand granites, the latter being especially abundant in the conglomerate lying above the Rewa sandstone.

42. Besides the diamonds lying still embedded in the conglomerates, others are found in the neighbouring detritus derived from the disintegration of the Vindhyan beds. The workings are developed accordingly—some with a view to the removal of the undisturbed conglomerate, and others with the intention of recovering the diamonds included in the more recently distributed detritus.

43. The undisturbed conglomerate is often covered by considerable thicknesses of younger Vindhyan rocks, and is reached by workings which are often, but not always, deep. These are referred to by Mr. Vredenburg as "direct workings." In other places the overlying younger rocks have been removed by weather-agents, and the conglomerate thus exposed at the surface is available for "shallow workings." In the detritus removed from the original conglomerate and deposited in river-valleys the diamonds may be reached by superficial, shallow, or comparatively deep workings, and they may be all spoken of conveniently as "alluvial workings."

44. Mr. Vredenburg has given the following list of workings examined :—

A. WORKINGS CONNECTED WITH THE SUB-REWA CONGLOMERATE.

(1) *Direct workings*—
Panna State: Shahidan, Chunha, Kalianpur (abandoned).
Charkari State: Khameria.

(2) *Shallow workings*—
Panna State: Maraia, Bandi, Bhawanipur, Harduapur, Srinagar, Ogra, Manakpur.
Bijawar State: Simra.
Chobpur State: Dia.
Patarkechar State: Majhgawan.

(3) *Alluvial workings*—
Panna State: Majgama, Old Panna, Chhota Manakpur, Kalianpur, Ganeshpur, Radhapur, Hardua, Babupur, Itwa, Birjpur.
Charkari State: Ranipur, Palti, Bajaria.
Chobpur State: Seha, Jhanda.
Patarkechar State: Banari.

B. WORKINGS CONNECTED WITH THE SUPRA-REWA CONGLOMERATE.

(1) *Shallow workings*—
Panna State: Sakeria, Tindini, Mohra, Durgapur, Singhpur.
Kothi State: Jhanda.

(2) *Alluvial workings*—
Panna State: Udesna.
Kothi State: Naigawa.

45. Mr. Vredenburg has given an interesting series of statistical results with regard to the crystallographic characters, weight, lustre, colour and origin of the diamonds collected during the quarter in which he examined the area. The area immediately around Panna appears to be still the richest part of the field.

46. Besides various improvements possible by more systematic organization of the shallower workings, Mr. Vredenburg points out that the constancy of the conglomerate over large areas, and the regularity of the gently inclined strata, would permit of sinking deep shafts to the dip with a view to mining out the diamondiferous conglomerate on a plan common to all bedded deposits. The extension of this work in

the direction of the dip would naturally depend on the results obtained in the shallower shafts with regard to the persistence of the diamonds with the conglomerate. Judging by the present cost of working and the estimated average return in diamonds, there appears to be a distinct margin of profit to be expected from systematic mining operations under the more expensive conditions of depths down to 200—300 feet. The work should, of course, be commenced on an experimental stage, and under the management of a competent mining engineer.

Engineering Questions.

47. The Director visited Dharmsála during May, and reported on the condition of the station after the earthquake of April 4th, with a view to determining the question of selecting a suitable site as civil head-quarters for the Kángra district, and of retaining the site now occupied as cantonments for one of the Gurkha regiments.

48. Mr. G. H. Tipper, on behalf of the Military Works Department, reported on a site near the Takatu, west of Quetta, as suitable for the construction of a large reservoir. His report has been sent to the Local Administration.

Gold.

Gadag, Dharwar district.

49. The Gadag gold-fields lie within the band of Dhárwár rocks which Mr. R. Bruce Foote distinguished as the Dambal-Chiknayakanhalli band,[1] but as the name *Gadag band* is more likely to get into general use, it is proposed to use it instead of the original longer name. Mr. Maclaren was deputed, with Sub-Assistant M. Vinayak Rao, to survey this area during the past field-season, and has been able to supplement the observations of Mr. Foote by a more detailed examination of the petrological characters of the rocks, the results of which will be published shortly in a separate paper.

50. The most interesting rock-type from the point of view of the origin of the gold is the carbonaceous argillite forming the "country" in which the auriferous reefs lie. Two main areas of this rock have been distinguished—the northern in which the Dhárwár Reefs mine and the Sangli gold mine are situated, and the southern of smaller area in the Bellâry district. Though these argillites are red in colour near the surface, they are black and carbonaceous in the deep workings of the

[1] *Rec. Geol. Surv. Ind.*, XXI, 49 (1888).

Dhárwár gold mines, the included iron-pyrites being oxidized and hydrated to limonite near the surface. The association of carbonaceous matter and pyrites in this area recalls the conditions in the Main Reef series of the Witwatersrand system in the Transvaal. Drs. Hatch and Corstorphine [1] quote a prevalent theory for the limitation of the gold to the Main Reef horizon as due to the presence of a reducing agent in the beds, and they instance both the pyrites and carbonaceous matter that are generally present. The pyrite most probably was itself the result of the reducing power of carbonaceous material acting on ferrous salts, and either or both would thus facilitate the precipitation of the gold from the solutions circulating at the high temperatures attending the intrusion of the associated igneous rocks.

51. The occurrence of the auriferous quartz-veins in the argillites of the Gadag band, distinguishes the conditions here from those of the Kolar field and the Hatti mining area of the Nizam's Dominions, where the gold-quartz veins are in hornblende-schists. Blue quartz-veins, like those that carry gold on the Kolar field, occur also in the Gadag band, but they have not been proved to be auriferous, and are regarded as older than the white quartz-veins, being considered to be genetically related to the igneous rocks from which the hornblende-schists were derived.

This occurrence of gold in quartz-veins other than the peculiar blue variety so well-known from Kolar should dispel the idea that gold is necessarily limited to this occurrence in the Dhárwár series. The deposition of gold is probably due to the accidental occurrence of very simple chemical conditions, such as a suitable reducing agent, in any locality where the essential physical conditions are satisfied, and the particular lithological character of its nidus is of secondary importance. The variety of material in which the metal may occur is so great that amongst the Dhárwárs no lithological type should be discarded as an impossible matrix, although the abundance of free silica naturally gives quartz more chances than any other rock-material of becoming the mother.

52. There is a certain amount of washing of river-sands in this area, but it is hardly worth the name of an industry, and the tests made by Mr. Maclaren during the course of his survey led to no promising results for alluvial gold.

53. Many of the outcrops of quartz-reefs in the northern part of the

[1] Geology of South Africa, 1905, 145.

Gadag band are honeycombed with old workings, and so far as they have been explored at Kabulayatkatti, these have been found to a depth of at least 300 feet. Assays from old pillars left in the workings show that some of the quartz worked carried 1½ ounces of gold to the ton. Abundant relics exist of mills for crushing quartz, affording a valuable index to the positions of auriferous reefs. Some of these are of the pestle-and-mortar kind; others consists of huge boulders made to rock to-and-fro in a hard bed-rock; others consist of a small stone rubbed along a groove in a larger stone, similar to those discovered by Mr. F. H. Smith in the Singhbhum district. The last kind is not common in this area, though it was the only one found near the ancient workings of Singhbhum.[1] In the neighbourhood of a watercourse hundreds of mortars of the first-named kind are often found grouped together; near the village of Nagavi as many as 218 were counted packed together on a single exposure of quartz-schist.

54. Active prospecting and mining operations have now been organised in this area by three or four companies, and leases of adjoining areas have been taken up with the intention of benefiting by the results of the more enterprising pioneers. The promising character of this area was noticed by Mr. R. Bruce Foote as long ago as 1874, but his description of the auriferous reefs remained unnoticed until Mr. Huddlestone and his coadjutors followed Mr. Foote's suggestions in 1900. The result has been the formation of the Dhárwár Gold Mines, Limited, and other companies now at work, with, in some cases at least, apparently good prospects of success. The field possesses certain natural advantages: it can be connected easily with the Southern Mahratta railway system; the climate is generally good, and abundant water for the development of electric power can be obtained in the Tungabhadra river some 20 miles from the field, when the mining operations reach a scale large enough to justify the capital outlay necessary for the plant. The chief present difficulty is the limited local supply of water for the large mills and works near the mines.

Wondalli gold-field, Nizam's Dominions.

55. Mr. Maclaren has also reported on the Maski band of Dhárwár schists, which is about 7 to 8 miles wide, stretching in an approximately meridional direction for about 45 miles across the Raichur Doab.[2] The

[1] *Rec. Geol. Surv. Ind.*, XXXI, 68 (1904).

[2] R. B. Foote. Geology of the Southern Mahratta Country. *Mem. Geol. Surv. Ind.*, XII, 41, 42 (1876); *Rec. Geol. Surv. Ind.*, XXII, 34 (1888).

northern or Wondalli section of this band appears to be the most important. Near its western border occurs the Hatti mine, which has shown a gradually increasing output of gold since March 1903. There is abundant evidence of old workings throughout this part of the band, in one case, near Hatti, reaching to a depth of 620 feet. These were referred to by Mr. R. Bruce Foote, who first called attention to the prospects of this area, but many more have been found by recent prospectors, and as one of the companies has now begun to return dividends, the thorough exploration and prospecting of the adjoining areas are assured.

The mode of occurrence and characters of the auriferous quartz in the Hatti mine agree in general with that of Kolar: the "country" is a similar hornblende-schist, and the gold-bearing quartz is typically of a translucent-blue or slate-colour, the younger series of associated white quartz-veins being barren; the blue quartz reef is in general parallel to the planes of schistosity of the country, dipping at a high angle to the westwards.

The chief rock-types of the band, besides the hornblende-schists already referred to, are altered diabases, chlorite-schists and a series of acid schistose rocks, possibly altered porphyries. The whole complex is crossed by younger diabasic intrusions as dykes, and along the northern boundary especially the schists have been attacked by granitic intrusions.

Manganese.

56. The investigation of the manganese-ore deposits, begun in the season 1903-04, has now been completed. Mr. L. L. Fermor, during the past field-season, visited the known deposits in the Jabalpur, Ganjam and Singhbhum districts, as well as those of the Jhábua State in Central India, the Panch Maháls, Nárukot and Sátára in the Bombay Presidency. Mr. J. M. Maclaren examined the occurrences of the Belgaum and Dhárwár districts, thus completing the recent examination of every occurrence of known importance except those of the Sandur State, which were described by Mr. R. Bruce Foote in his memoir on the Bellary district.[1] The preparation of a memoir dealing with the known occurrences of manganese ore in India has been entrusted to Mr. Fermor.

[1] *Mem. Geol. Surv. Ind.*, XXV, 194 (1895).

57. The first summary of Mr. Fermor's results shows that the manganese-ore deposits of India can be roughly classified as follows :—

A. Braunite, psilomelane and pyrolusite associated with, and derived from, manganese-bearing silicates (such as spessartite, rhodonite and less frequently piedmontite) occurring as bands and lenticles in the Archæan schists and gneisses Examples of these occur in—

(1) Nárukot in Bombay;
(2) *Jhábua* in Central India;
(3) *Bálaghát*, *Bhandára*, *Chhindwára* and *Nágpur* in the Central Provinces;
(4) Ganjám and *Vizagapatam* in Madras;

B. Psilomelane and pyrolusite superficially formed on the outcrops of rocks of Dhárwár age—

(1) Singhbhum in Bengal,
(2) Dhárwár, and Panch Mahâls in Bombay;
(3) Jabalpur in the Central Provinces;
(4) *Sandur Hills* in Madras;

C. Psilomelane and pyrolusite associated with, or contained in, laterite. Localities:—

(1) Belgaum and Sátára in Bombay;
(2) Jabalpur in the Central Provinces.

The localities in italics are those in which economically important deposits have been located and in most cases worked. Belgaum may possibly be added to these in the future. It will be seen that from every point of view, economic, mineralogical and petrological, the chief interest centres in the deposits of group A.

Vizagapatam district.

58. As the result of a close examination of some of the manganese-ore deposits of the Vizagapatam district, and especially of the Kodur Mines, where the quarrying has now been in progress for over thirteen years, Mr. Fermor has been able to formulate a definite theory as to the origin of the manganese-silicate rocks from which, as indicated last year,[1] he regards the manganese-ores as having been derived, at least in part, by chemical alteration, and this theory, he asserts, can be applied in a more or less modified form to the rocks of similar nature occurring in the Archæan complex of other parts of India.

[1] *Rec. Geol. Surv. Ind.*, XXXII, 145.

59. The Vizagapatam district, geologically speaking, consists of a complex of Archæan rocks, which has been separated into three groups—(1) the Khondalite series (2) the Charnockite series and (3) the Gneissose granite. The manganese-ore bodies have been found only in close relationship with (1) and (3), and briefly stated, the conclusions as to their origin are as follows:—

(*a*) Rocks containing a large proportion of manganese-silicates, such as spessartite and manganese-pyroxenes, and of which the most general and characteristic type is apatite-spessartite-felspar-rock, have been intruded in Archæan times, as part of an igneous magma, into the rocks of the khondalite series.

(*b*) Under the influence of chemical waters, doubtless heated, the manganese-silicates have been decomposed, and the manganese has been removed from some parts of the rock-mass and re-deposited in the form of oxides in other parts, and so added to the manganese already there, replacing at the same time any felspar not already decomposed and removed.

60. This theory can be stated in more precise detail, in a form especially exemplified by the Kodur and Garbhám mines, as follows:—

(*a*) The original magma had a composition corresponding to a mixture of apatite, felspar, quartz, spessartite and various manganese pyroxenes.

(*b*) This magma, while still molten, became differentiated into various units.

(*c*) The magma was then erupted and intruded, probably into the rocks of the khondalite series; on solidifying the following rocks, among others crystallized out:—

(1) Felspar-rock,
(2) Felspar-quartz-rock,
(3) Spessartite-felspar-rock,
(4) Spessartite-pyroxene-felspar-rock,
(5) Spessartite-pyroxene-rock,
(6) Spessartite-rock,
(7) Apatite-spessartite-felspar-rock.

(*d*) The basic manganiferous rocks 3 to 7 were probably distributed as streaks and patches in the more acid rocks 1 and 2.

(*e*) Hot mineral waters then attacked these manganiferous rocks,

probably at once, but at any rate in Archæan times, and as the result of this action manganese-ores were formed in two ways. In many cases manganese was taken into solution and carried to another part of the rock-mass, where it was deposited so as to replace all the minerals of the rock except those containing manganese, which in some cases remained fresh and unaltered and in others were also broken up. Thus the manganese-ore resulting from the replacement of rock No. 7 sometimes consists of compact psilomelane studded with bright-red and orange spessartite-garnets, and at other times entirely of manganese-ore. In the case of mass of spessartite-rock, however, the alumina and silica were carried away, leaving a porous mass of manganese-oxides, which were more or less consolidated by the introduction of more manganese-oxide from other parts of the deposit.

(*f*) Another result of the series of chemical changes taking place has been the conversion into kaolin and lithomarge of almost all the felspar; and, as a further consequence of the removal of material from one part of the rock-mass to another, there has been a frequent adjustment of equilibrium, producing small slips and folds.

Such an explanation as the above satisfies all the requirements of the majority of the Vizagapatam deposits and accounts well for the extraordinary jumble of rocks seen at Kodur.

Ganjam district.

61. A few occurrences of manganese-ore were investigated in the Ganjam district. They are of no economic value, but are interesting because they are associated in one case with spessartite-felspar rock and in another with spessartite-rhodonite rock.

Central Provinces.

62. The typical rock from which the manganese-ore deposits have been derived in the Central Provinces is a spessartite-quartz rock, often containing a small quantity of apatite, and usually quite free from felspar. Although the evidence is not so conclusive as in the Vizagapatam district, yet it seems probable that here also the original manganese-bearing rock was intruded in the molten condition into the metamorphic schists and gneisses. The manganese-ores of the Central Provinces, besides being much less phosphoric than those of Vizagapatam, are much more largely braunite; and while the manganese-ores of Vizagapatam are often cavernous, porous and friable, those of the Central Provinces are almost invariably very compact, hard and more or less crystalline.

63. The manganese-ores in the Jabalpur district occur in a series of rocks belonging to the Dhárwárs. These rocks are chiefly quartzites, shales, slates and hematite-schists banded with jaspery quartzite.

Jabalpur district.

The manganese-ores can be divided into two classes:—

I. Manganiferous iron-ore and psilomelane.

II. Pyrolusite.

The banded jasper-hematites have often been converted at the outcrop into large masses of manganiferous limonite, forming caps to the ridges in which these rocks occur. This manganiferous limonite is simply limonite veined with psilomelane, which in places forms large segregations. In other cases the hematite-schists have, by the development of little veins of manganese-ore, been converted at the outcrop into manganiferous hematite. The manganese has in both cases been no doubt derived from the small percentage of this element contained in the hematite; in some cases this concentration of manganese has proceeded to such an extent that considerable quantities of nodular psilomelane have collected on the hematite outcrops. At the same time, the accompanying jasper, slate and sericite-phyllites have often been converted into manganese-ore by replacement. The pyrolusite usually occurs as nests and strings in the Gosalpur quartzites of Mr. P. N. Bose,[1] and as nodular segregations in the laterite débris often covering these rocks. It, also, has no doubt been derived from the hematite-schists.

64. The manganese-ore deposit at Kájlidongri (22° 57′; 74° 31′) near Meghnagar railway station consists of much folded, alternating quartzite and manganese-ore layers, associated with spessartite and rhodonite-bearing rocks; it is to be classed with the Central Provinces deposits rather than with those of Vizagapatam. This deposit possesses especial interest on account of two new minerals which it has yielded. One of these is the blue amphibole described in *Rec. Geol. Surv. Ind.*, XXXI, p. 235. The other is, according to an analysis made by Mr. H. J. Winch, a manganate of barium, iron and manganese, corresponding to the formula $(Ba_3, Mn_3, Fe_2{}^{iv})_2 (MnO_5)_3$, and is consequently a crystalline mineral closely allied to the amorphous mineral psilomelane.

Jhabua State, Central India.

[1] *Rec. Geol. Surv. Ind.*, XXII, 218 (1889).

65. The manganese-, and manganiferous-iron-ores of Singhbhum, first noticed by V. Ball[1] are very similar to those of Jabalpur. They consist chiefly of psilomelane formed by the superficial replacement of sericitic phyllites, quartzites and felspathic grits, which may be doubtfully referred to the Dhárwár system.

Singhbhum district.

66. The manganese-ores of the Panch Mahâls district, Bombay Presidency, consist of psilomelane and pyrolusite and have been formed by the superficial replacement of slates and quartzites of the Chámpáner (Dhárwár) series.

Panch Mahals district.

67. Near Jothvád, about two miles north of Jambughora (22° 22′; 73° 48′) in the Nárukot State the schists and gneisses with which the manganese-ores are associated have been invaded by a porphyritic biotite-granite, which in places is studded with xenoliths of the manganiferous rocks, partially converted, in some cases, into manganese-ore. The granite is similar to that of Bundelkhand and of other areas where there is little doubt of its Archæan age. It seems likely, therefore, from this occurrence, that the development of manganese-ore from the manganiferous silicates took place in Archæan times.

Narukot State.

68. Mr. J. M. Maclaren paid a brief visit to the manganese-ore deposit at Talevadi (15° 33′; 17° 34′) then being developed by Messrs. Jambon & Cie. He found the manganese-ore to occur as more or less spherical concretions in a deposit of laterite 15 to 20 feet thick; they exhibited in the pits sunk a gradual passage downwards into quartz-schist; this in its turn rests on a slightly manganiferous limestone, which, like the quartz-schist, is of Dhárwár age.

Belgaum district.

69. Amongst other localities for manganese-ore in the Dhárwár district Mr. Maclaren visited Chik-Vadvati (15° 10′; 75° 47′), long ago examined by Newbold in the Kappatguda Hills, Sangli State.[2] He found the manganese-ores to occur on the outcrops of banded, limonitic, jaspery quartzites of Dhárwár age, and his specimens show that they must have had an origin precisely similar to those of the Jabalpur district. They likewise are of no economic value.

Dharwar district.

[1] *Mem. Geol. Surv. Ind.*, XVIII, 147 (1881).

[2] *Journ. Roy. As. Soc.*, VII, 212 (1843).

70. The manganese-ores of the Mahábaleshwar and Yeruli (18° 2'; 73° 54') plateaux in the Sátára district occur as concretions of psilomelane in a small thickness of lateritic soil, resting on the Deccan Trap. They never occur in sufficient quantity to pay for extraction, and have probably been formed by concentration of the manganese which all such basic lavas must contain.

Satara district.

Salt.

71. At the time of writing the last General Report our information with regard to the amount of salt included in the Sambhar Lake mud had been estimated at 6·40 per cent. as the average of 148 samples taken at depths of 4, 8 and 12 feet at different parts of the lake-bed. It was found, however, that the mechanical construction of the sampler used favoured the muddy layers, which, being less permeable, contained a slightly higher percentage of salt than the sandy layers. I accordingly designed a borer which would remove this source of error, and in order to ensure a perfectly uniform sampling of the whole lake-surface, divided the area into rectangles of one mile long and half-a-mile broad by a series of north-south lines at one-mile intervals and a series of intersecting east-west lines at half-mile intervals. At the points of intersection of these two systems of lines the Assistant Commissioner, during April and May, 1905, obtained samples with the new boring machine at a constant depth of 4 feet below the surface These samples, 129 in number, have now been analysed, and give an average of 5·21 per cent. of sodium chloride. At the same time, the specific gravity of the mud has been determined to be on an average 1·641. The total quantity of sodium chloride in the upper 4-foot layer of lake-silt over an area of 68 square miles is thus:—

Sambhar Lake.

$$\frac{4 \times 1{\cdot}641 \times 62{\cdot}425 \times 68 \times 27{,}878{,}400 \times 5{\cdot}21}{2{,}240 \times 100} = 18{,}607{,}000 \text{ tons.}$$

Without considering any further introduction of salt into the Lake, we have, in the dry season, a total of $4\frac{1}{2}$ million tons of salt for every foot depth of silt, and as it was found by the first set of borings that the 8 and 12-foot levels are slightly richer than the 4-foot level, we can safely assume the existence of this proportion of salt to a depth of at least 12 feet. Thus, the annual removal, by manufacture, of

122,000 tons from the upper layers of silt makes no serious inroad into the total stocks of salt in the lake-mud: the uppermost layer one-foot thick contains about as much salt as has been removed by the operations of the 35 years during which the Sambhar Lake has been under the control of Government.

72. As previously reported, our investigation has shown that the silt extends under the central east-west axis of the Lake to a depth of about 65 feet, whilst samples of mud from this depth have given 5·59 per cent. of salt. To estimate the total quantity of salt in this body of silt below the layers affected by manufacture would be mere playing with numerical curiosities; it is sufficient for the time being to state that we are now certain of the existence near the surface of practically an unlimited quantity of salt, and this assurance gives us leisure to tackle the practical question of determinating the fraction that can be readily extracted by the present or an equally economical process of manufacture.

73. The process by which the salt passes into solution to make the annual stock of lake-brine is a complicated combination of superficial leaching by the fresh water spreading over the surface when the tributary rivers are in flood, and of rise in the level of subterranean brine. For the preparation of the lake-brine and for the processes of subsequent manufacture, an abundance of water is essential, and, as stated before, no interference with its inflow from the surrounding country should be permitted. The main difficulties to be feared are the general rise of the lake-bed surface by the inflow of silt, and the increase in proportion of the associated sodic salts – sulphate and carbonate—which are rejected and returned to the Lake during the process of salt-manufacture.

74. The sodic salts now exist together in the lake-mud in the proportions of chloride 77·2, sulphate 13·9 and carbonate 8·9. The analyses made in 1869 were far too few to rely on as accurately representing the state of affairs when the Lake was taken over, but it is significant that they all agree in showing, with regard to the lake-mud, the subterranean-brine and the lake-brine, that there has since been a distinct though small reduction in the ratio of chloride to other sodic salts. As long as the present process continues, of extracting the chloride only, the difficulty of manufacturing pure salt will gradually increase, and although this increase is small, it ought to be considered: undoubtedly the correct course is so to arrange the process of manufacture that the sulphate as well as the chloride, and

possibly also the carbonate, should be turned to marketable account. In view of the limited quantity of water available, the erratic character of the seasons and the great diurnal range of temperature during the dry season, the problem is far too complicated to be settled by purely theoretical deduction from present knowledge. We know enough about the behaviour of pure solutions of all three salts to predict their behaviour under all conditions of temperature; but about their behaviour when present together in a compound brine, complicated by deoxidation due to algous growths, we know practically nothing: the whole question is worth most careful research, not merely because of its scientific interest, but on account of our inability at present to prove that the statements of the Salt Officers with regard to the increasing difficulty of manufacture are but a temporary phase in the history of the Lake. The rise in the proportion of other salts is small and possibly at present unimportant; the rise in the level of the silt is perhaps more serious; but, whatever may be the cause, it would be humiliating to watch the failure of this Lake when one knows for certain that it contains, in its uppermost ten feet of silt, enough salt to supply the requirements of this section of the Salt Department for another 300 years.

GEOLOGICAL SURVEYS.

Burma.

Northern Shan States.

75. Messrs. LaTouche and Simpson were employed throughout the field-season in the Northern Shan States, the latter officer confining his work to the coal-bearing areas, which are referred to in another part of this report (page 86). Mr. LaTouche was occupied for most of the season in checking and revising, according to our new lights, the areas previously mapped by Messrs. Datta and Pilgrim, the only new ground surveyed being that lying between the Loi Pan range, on the southern border of standard sheet No. 381, and the Namma coal-field.

76. One of the objects kept in view during the course of this work was the prospect of distinguishing the stratigraphical constituents of the great masses of limestones which stretch over large areas on the Shan plateau. The lithological variations are not sufficiently pronounced and persistent to enable the field worker to accept such characters as a guide in mapping exposures discovered at distances from the fossiliferous localities: the difficulties are accentuated, as explained in

previous reports, by the original features of the rock being masked over considerable areas by thick jungle, and by a deep crust of decomposition products. The additional observations made during the past season have increased the complexity of the problem rather than produced a practicable classification for guidance in mapping. Mr. LaTouche has discovered at one locality, Nam-un (22° 18′; 97° 41′) a highly fossiliferous band in the plateau limestones, crowded with *Fenestellæ* and other fossils of Middle Productus age similar to those found in the Southern Shan States by Mr. Middlemiss in 1900. He has found also by microscopic examination of a number of limestones that foraminifera of a Carboniferous facies are more widely distributed than was formerly thought to be the case. There are recognisable lithological differences between these presumably Carboniferous limestones and those that form the prevailing type amongst the Plateau limestones, which are regarded as Devonian in age from the fossils they have yielded at various points. But our experience shows that it is dangerous to accept these lithological characters as a guide in correlating other exposures where fossils are not found or are unrecognisable. Geological mapping in this area is thus reduced to its most empirical and mechanical form—the mere recognition of isolated fossil-bearing spots separated by wide stretches of limestone, to which it would be dangerous to apply a stratigraphical colour. As the country becomes opened up, the list of fossiliferous localities will doubtless increase, and will be found to arrange itself into a skeleton map; but at present we are very far from being able to divide the country into areas with any classification recognising units as small as an ordinary stratigraphical system.

77. In 1903 Mr. Pilgrim had noted some igneous rocks associated with the Upper Silurian sandstones in the neighbourhood of the Nam-tu river to the north-west of Hsi-paw, which he considered to be intrusive. These rocks Mr. LaTouche found to be conglomeratic in places, and interbedded with the sandstones; there seems little doubt consequently that they are contemporaneous beds of volcanic ash. Similar beds were found in the Silurian sandstones at the head of the Nam-Pawng valley, to the south-east of Lashio. Volcanic activity seems therefore to have extended over a wide area at this period.

78. There is still some uncertainty about the stratigraphical position of the Napeng shales, the fossils from which are now being examined in England. As they are of Triassic or Rhætic age, they might be expected to be found associated with and below the red sandstones,

(Nam-yau or Hsi-paw series), which there is little doubt are Jurassic; but so far they have not been found in this position over the large area now examined, the red sandstones being found frequently to rest upon the Plateau limestones. At Htengnoi (22° 24'; 97° 21') Mr. LaTouche found a blue limestone at the base of the red sandstone series, similar to a limestone associated with the Napeng shales at Kyaukkyan and Hsonoi, resting on a conglomerate containing pebbles of the Plateau limestone, and this in turn resting on the upturned edges of the latter, but the shales were not found in this section. This section seems to point to a considerable interval between the periods of deposition of the general Plateau limestones and the Napeng series. The Napeng shales appear to have had a wide distribution, for Mr. LaTouche found a patch of them far to the east at Lukhkai (22° 55' 30"; 98° 13' 30"). Here also there are no means of ascertaining their exact position in the series.

Central India.

79. For the field-season 1904-05 a survey party under the superintendence of Mr. C. S. Middlemiss was organized to commence mapping the previously unsurveyed band of country stretching northward and westward from the Bhopal State. Mr. Vredenburg's work during the season 1897-98, covered the eastern margins of standard sheets Nos. 356, 357 and 358 and the southern fringes of 355 and 376. In order that the stratigraphical lines then established in detail might be extended without a break into the unknown ground, Mr. Vredenburg was attached to the Central Indian party for the first few weeks, the whole party working jointly over the ground covered by sheet 376. All the members of the party having become familiarized with the formations which were previously unknown to them, and having agreed on the system of nomenclature, Mr. Vredenburg was withdrawn for his work at head-quarters, and the remaining three officers separated to take up independent areas. The standard sheets completed during the season were Nos. 355—358 and 376 whilst parts of Nos. 332, 353, 354, 374 and 375 were also surveyed.

The operations in the field and subsequent recess work at head-quarters have been conducted in a way that reflects credit on Mr. Middlemiss's organization: each officer has submitted a detailed progress report, neatly finished maps, and a representative collection of specimens, thus carefully observing the necessary mechanical

requirements of the survey, which are too often neglected for the more interesting distractions of scientific problems.

Principal results of interest.

80. The great system of Vindhyan sandstones, flagstones and shales so finely developed in Mr. Vredenburg's described area, continued to monopolise the cartography through the remainder of standard sheet 376, and even continued in the form of small detached inliers into portions of sheets 354, 355 and 375. The rest of the area is appropriated by Deccan Trap, here and there showing a few patches of laterite, alluvium in the main river and stream-beds, and cotton soil.

81. The following tabular scheme shows the formations and rock stages represented in this part of India :—

Table of Geological Formations.

Alluvium		(*a*) of present rivers and streams. (*b*) of Narbada valley.
Laterite		(*a*) A few small caps to hills and patches in river beds.
Deccan Trap (with intertrappeans)		(*a*) in small irregular patches among Vindhyans. (*b*) as great plateaux.
Upper Vindhyans.	Upper Bhander (Bundair) sandstone.	(*a*) forming wide plateaux. (*b*) as hilly inliers among Deccan Trap.
	Sirboo shales	Occasionally exposed at base of scarps.
	Lower Bhander (Bundair) sandstone (with subsidiary band of Sánchi shales.)	Forming rolling hills and ridges.
	Ganurgarh shales	Occasionally exposed at base of scarps.
	Upper Rewa sandstone	Rolling low ridges.
	Jhiri shales	One small exposure.
	Lower Rewa sandstone	Forming scarped ridges.
	Kaimur sandstone (with conglomerate at base.)	Forming scarped ridges.
Lower Vindhyan Shales		One small exposure.
Crystalline gneisses and schists		A few exposures in Narbada valley.

Crystalline gneisses and schists.

82. A small exposure of crystalline gneisses and schists, whose age is doubtful but placed tentatively with the Archæans, was met with by Mr. Walker in the bed of the Narbada river near Chhipaner. They are steeply folded, wtih a N.W.—S.E. strike, and include granitic gneisses and schists showing " crush " structure, and composed of the minerals, quartz, felspar (orthoclase and plagioclase), muscovite, hornblende, augite and sphene; together with various other associated rocks such as amphibole-(often blue-green actinolite) quartz-epidote rock; other schists and gneisses, and ancient basic dykes.

Lower Vindhyan Shales.

83. Lower Vindhyan rocks are only rather doubtfully displayed in one small exposure at the base of Bamnor hill, 7 miles north of Amrawad (sheet 376). They are sombre-tinted, micaceous and ferruginous shales, and the chief reason for supposing them to belong to the Lower Vindhyans is that they underlie the Kaimur conglomerate, but without any apparent unconformity.

Upper Vindhyans.

84. With regard to the Upper Vindhyans, all the various members of that sequence from Kaimur sandstone and conglomerate to Upper Bhander (Bundair) sandstone, as correlated by Mr. Vredenburg, were traced out of his area and mapped up to their disappearance under alluvium or against the Deccan Trap. The nomenclature throughout is Mr. Vredenburg's, with reference to which it should perhaps be stated that whilst the lowermost and uppermost formations may, with a fair amount of confidence, be accepted as correctly correlated with the formations of the same name further east in the Central Provinces (from which the local Vindhyan stage names were originally taken) there is still a shade of uncertainty attaching to some of the intermediate rock stages, especially those of the Rewa group. In spite of a careful search made on all possible occasions, these Upper Vindhyans still remain unfossiliferous, although the sometimes fine-gained sandstones and unmetamorphosed shales (often ripple-marked and current-bedded) afford most suitable material for the preservation of ordinary fossil remains. The general strike of the Vindhyans over this area is no longer parallel to the so-called Vindhyan or Kaimur ranges, *i.e.*, E.N.E.—W.S.W., but takes a direction nearly N.W.—S.E., the axis of the folding following along a gentle synclinal a little east of Bhopal town, with dip angles from as much as 12° to as little as 1° or 2°.

85. The Deccan Trap appears at first sight to be very simply understood under the ordinarily accepted theory that it constitutes a relic of a great lava-flood which once covered in the whole of this area to a considerable height above the present Vindhyan hill-tops, and out of which the ancient pre-trappean landscape has again been partially brought to light by differential denudation.

Deccan Trap.

So far as met with in these parts, it may be said to be a micro-crystalline basalt without olivine.[1] It possesses a considerable glassy content, partly in the form of an unindividualised base between the micro-crystals of plagioclase and monoclinic pyroxene, but chiefly in that form so characteristic of the Deccan Trap, namely, as irregular, small, amœbiform vesicles lined and filled with orange-coloured or green basic glass (palagonite). Other spherical pea-shaped gas pores are "stopped" by green-earth and zeolites, whilst the larger geodes contain all the various forms of crystalline and colloid silica, with calcite and zeolites that are so commonly met with in the Deccan Trap country.

It is chiefly owing to the varying amounts of glass vesicles and pores filled with zeolites, etc., that the trap has resisted weathering differently, and so comes to possess now a "bedded" character; for otherwise there are here no pyroclastic agglomerates or ashes, and no sufficiently varying mineralogical habit in the different layers to suggest time intervals or flows from different sources.

Intertrappeans have been found at two or three places, (some with recognisable fossils by Sethu Rama Rau), but the occurrences are very local, and nowhere constitute a horizon from which we can reckon up and down.

In the large area, consisting almost wholly of Deccan Trap, surveyed by Mr. Walker, the whole country-face, from near 2,000 feet in the plateau hills at Sehore to about 1,000 feet at the foot of the Ghâts in the direction of the Narbada valley, has the general appearance of being a series of steps, platforms or superposed layers, about ten in number, of slightly varying character; some being columnar, some weathering spheroidally and others decomposing into a soft, indeterminate mass. Such is the rather weak and somewhat ambiguous evidence for considering the Trap to consist of ordinary bedded flows with a distant source.

On the other hand, a good deal of the Deccan Trap has no definite

[1] Mr. Walker notes the occurrence of doubtful serpentine in some slides.

structural planes at all and even where beds of different shades of texture and composition are found, attempts at correlating separate bands across intermediate areas have been only locally successful (Walker).

But the strongest argument against the theory that the Trap country attained its present configuration altogether by the action of denudation on a solidified set of lava-flows, which for great distances had horizontally overspread the subjacent Vindhyans, consists in cumulative negative evidence. The chief fact illustrating this (among many others too complicated for summarisation) is the almost universal absence of recognisable outliers of the Trap on the Vindhyans, and the total absence of detached masses of it occupying ledges and intermediate slopes among the great array of Vindhyan scarps and counterscarps. Hence Mr. Middlemiss is inclined to think that underground sills, with partial and local extrusion as fissure eruptions, are best able to account for what would otherwise be most strange behaviour for a horizontal overlying formation after dissection by denudation such as the trap areas have suffered. The above fact, so locally apparent here, is also illustrated on a large scale by the general appearance of the Deccan Trap areas over the general map of India, which always hang together in a connected whole and are never broken up into outlying and completely separated areas of any considerable magnitude.[1]

Laterite.

86. The laterite of this area, though slightly developed as tiny ferruginous caps in sheet 376, is principally confined to the northern half of 355 and to portions of 354, 353, 374 and 375. The southern sheets surveyed by Mr. Walker yielded none.

It has most of the characteristics of the typical high-level laterite recently shown to be highly aluminous, is from 50 to 80 feet thick, and usually is in patches less than a mile broad by several miles long, arranged disconnectedly in rows along old planes of denudation or gentle slopes. Each patch usually presents a steep cliff-like face on one side, whilst on the other it finishes flush with the higher parts of the slopes or becomes covered by alluvium under which it appears to

[1] Many of the smaller apparent outliers such as those in the Rewa-Gondwana coal basin are admitted to be horizontally intrusive sheets and dykes by Hughes (*Mem. Geol. Surv. Ind.*, XXI, pt. 3, p. 74), the only conclusion possible from their surface occurrence as mapped by him.

sink with a gentle dip. Some laterite found by Sethu Rama Rau has proved to be very highly aluminous, one sample from the 1,844-feet peak, about 6 miles S.E. of Bairasia [Reg. No. 19-65] containing 59 per cent. of $Al_2 O_3$. It occurs as pale-coloured lumps scattered about among the débris-covered slopes and cliff falls, and therefore occurs only sporadically among the ordinary ferruginous laterite.

Alluvium.

87. The alluvium has been indicated on the geological maps whenever it exceeded 10 feet in thickness. This was necessary, partly because of the importance of it as a formation (often 40 feet thick as in the Betwa valley) and partly because in some places it so obscured the solid geology as to make the mapping of the latter below it impossible.

Cotton-soil.

88. Cotton-soil universally covers the Deccan Trap areas as a carpet of from a few inches to as much as 4 or 5 feet. It is sometimes quite black but generally of a dull-grey colour, and contains quantities of rounded, shot-like grains of kankar.

Central Provinces.

89. Mr. P. N. Datta was employed during the season 1904-05 in the Central Provinces, mapping previously unsurveyed areas in parts of the Nágpur, Bhandára, Bálaghát and Seoni districts included in quarter-sheets 72 N.E. and S.E. The rock-groups within this area included (*a*) granites and gneisses forming the fundamental complex over a large part of the ground, (*b*) a series of unfossiliferous rocks of sedimentary origin resembling some of those known in South India as the Dhárwárs, (*c*) the Lameta series and (*d*) the Deccan Trap. The groups mapped are similar to those known in other areas, and their examination led to the discovery of no unusual features.

Persian Gulf.

90. Mr. G. E. Pilgrim was deputed to make a tour in the Persian Gulf and accessible parts of the adjoining mainlands during the field-season 1904-05. He has produced a preliminary report of his results, and is now engaged on a detailed description of the fossils and minerals collected. The work done was necessarily little more than a reconnaissance of most parts of the area, but the data collected form a material addition to the information recorded by previous

travellers, such as W. K. Loftus, H. J. Carter, and W. T. Blanford, and give us a fairly clear idea of the geological history of the region.

The following is a list of the formations examined:—

Shelly conglomerates and dead-coral reefs of the littoral; red sandhills of the coast of Trucial 'Omán; alluvium of Mesopotamia; river and lake deposits of 'Omán and the interior of Persia	*Recent or sub-recent.*
Foraminiferal oolite or "Miliolite" . .	*Pleistocene.*
Bakhtiyári series, grits and conglomerates. A portion of the Makrán series . . .	*Pliocene.*
Makrán series, marls, clays, and sandstones with limestones and interbedded strata of rock-gypsum	*Upper Miocene.*
Clypeaster beds of the Bakhtiyári mountains .	*Lower Miocene.*
Nummulitic limestone of Persia, Maskat series, and Bahrain series	*Oligocene and Eocene.*
Hormuz series, lavas and tuffs with interbedded clays and sandstones	*Upper Cretaceous or Lower Eocene.*
Hippuritic limestones of Persia and 'Omán .	*Upper Cretaceous.*
Serpentinous and other igneous rocks of 'Omán	*Jurassic or Lower Cretaceous.*
'Omán series, limestones and slates with beds of chert	*Carboniferous to Trias.*
Hatát beds, schists and quartzites . . .	*Archæan.*

91. The formations distinguished as the *Hatát series* are regarded as Archæan, purely from their lithological characters being in general agreement with the Dhárwárs of Peninsular India. They consist of mica-schists, hornblende-schists, talc-schists, quartz-schists, calc-schists and quartzites. Great masses of quartz penetrated all these beds previously to the great crushing stresses which have deformed, foliated and metamorphosed quartz-veins and sedimentaries alike. They occupy various plains, of which Saih Hatát is the largest, and are surrounded by cliffs of the next series. They are also seen on the edge of the great Samáyil valley and near the coast of 'Omán to the south-east of Maskat.

92. Under the name *'Omán series*, Mr. Pilgrim has separated formations consisting mainly of limestones, many of which have been rendered quite fissile by crushing, while some are massive. Interbedded are a few shales, slates and sandstones, with red and green chert-beds. Traces of fossils have generally been obliterated,

but in one place the presence of *Productus, Dielasma* and other brachiopods point to a Carboniferous age for that portion, while a species of *Myophoria* from the Elphinstone Inlet indicates another portion as Triassic. The whole must at present be considered as a single series extending from Jabal Ja'alán, near Rás-al-Hadd, through the whole of 'Omán to the end of the Ruūs-al-Jabal peninsula, and forming the great mountain ranges of 'Omán of which Jabal Akhdhar is the best known. Rocks of this series crop out on the Persian side of the Gulf both east and west of Linga, and on the little island of Daiyīna off the coast of Trucial 'Omán. A great abundance of basic igneous material has been injected in the form of sills of immense thickness into the 'Omán series, or has flowed over their denuded surface, including diabase, diorite, gabbro and dolerite. These rocks have been largely altered into epidiorites and serpentine. The dark-greenish cliffs of Maskat for the most part consist of the last-named, the joints being filled up with magnesite. This volcanic series has shared in all the folding of the 'Omán series, and both igneous rocks and limestones alike dip at angles which are hardly ever less than 45°. It is unconformably overlaid by Upper Cretaceous limestones, and we may therefore conclude that this outpouring of volcanic material probably took place at the end of the Jurassic or at the beginning of the Cretaceous period.

93. As previously known in a general way, limestones containing members of the characteristic family of the *Hippuritidæ*, with some interbedded shales, are widely diffused throughout Persia. A small inlier is found at Khamīr surrounded by younger rocks, and it is well developed on the Arabian coast to the south-east of Maskat, where rocks whose fossils indicate an Upper Cretaceous age overlie the older rocks unconformably.

94. Occupying the whole of the eastern or larger portion of the Persián Gulf proper are series of lavas and tuffs with some interbedded sand-stones and shales known as the *Hormuz series.* Associated with these are vast beds of rock-salt and gypsum, deeply tinged with red from the presence of red iron-oxide (red ochre) produced by the decomposition of specular iron-ore which is abundantly found throughout the formation. Iron-pyrites, sulphur, dolomite and anhydrite are found also to some extent in the deposit. The underground solution of the salt and the consequent falling in of the surface has given the ground occupied by the Hormuz series a singularly

craggy aspect, and their almost entire barrenness increases the peculiarity of their appearance. The beds have been greatly disturbed and are almost always found to dip at high angles. At Khamir their connection with the Hippuritic limestone clearly proves that their age is not older than Upper Cretaceous, and as the eocene rocks which overlie them are probably not older than middle eocene, a date between these two periods may be assigned to them. The rocks of this series are thus as nearly as possible contemporaneous with the Deccan Trap of India, and it is not unlikely that the rhyolitic lavas represent the acid differentiation products from the magma which gave rise to the predominant basic lavas further east (*vide supra*, page 78).

95. Rocks of eocene and oligocene age are distributed in three distinct areas in the Gulf:—

1. Persia. Nummulitic limestone extends over great areas in the interior of Persia and Baluchistán, overlying the Cretaceous rocks unconformably. Sandstones with interbedded limestones of an upper eocene age form the big range running behind Bandar 'Abbás and approaching the sea at Khamīr. Southern Persia probably does not contain any representative of the lower eocene limestones of Baluchistan and Sind, but a more or less uninterrupted deposition seems to have continued into oligocene or even into lower miocene times. The newest beds seen are limestones containing *Clypeaster* in the Bakhtiyári mountains.
2. 'Omán. Sandy limestone, with a basal conglomerate, belonging to the upper eocene rests on all the older beds.
3. Bahrain. This area was separated from the preceding two areas by a land barrier consisting of the older rocks of 'Omán and of the once continuous land formed by the Hormuz series, of which the Gulf islands and a few places on the mainland are now the sole surviving remnants. The rocks are limestones, often very argillaceous, and characterized by the large amount of gypsum and siliceous matter scattered through them, the latter as flint, chert or quartz geodes. Nummulites and echinoids are numerous in some beds. The Bahrain series almost certainly occupies a large area in the interior of Arabia, and probably is a representative of the Egyptian eocene, with which it shows strong fossil affinities.

96. Blanford's *Mekran series* is widely spread in the Gulf region. It consists mainly of indurated marls and clays veined with gypsum, with interbedded limestones and sandstones, probably attaining a thickness of more than 5,000 feet. It forms the Gīsakán range behind Bushahr and is found practically all along the coast. Inland it reaches an elevation of 7,000 feet above the sea. It rests unconformably on the Hormuz series and on Nummulitic limestones of oligocene age. The basal beds contain a great thickness of rock-gypsum amounting to at least 300 feet. It is in this part of the series that most of the petroleum of Persia and the Gulf occurs. These basal beds do not appear to extend to the east of Bandar 'Abbás, having probably been overlapped by newer beds. The fossils met with in Kishm, Hanjám, and other islands also indicate that this portion of the series is newer than the great mass of clays in the interior of Persia, and it will probably be found convenient to restrict the name Makrán to these newer beds, adopting a new name for the remainder.

An interesting feature in connection with this series is the occurrence in it of rounded nodules formed as concretionary structures around fossil nuclei. A collection of fossils from these nodules has recently been studied by Messrs. R. B. Newton, H. W. Burrows and H. Woodward, the relationships being shown to be predominantly pliocene.[1]

97. Under the name *Bakhtiyári series*, Mr. Pilgrim has separated a set of beds resting with slight, but distinct, unconformity on the Makráns. They do not approach to within a distance of 50 miles of the Gulf, but are largely developed inland stretching from Mūsal to Shiráz and appearing in the hills of Ahwáz and Bahbahán, and amid the Bakhtiyári mountains. Red sandstones, grits and conglomerates are the prevailing rocks. A conglomerate containing pebbles of red and green chert is a characteristic and widely-spread rock in the series. These rocks also rest unconformably on eocene and Cretaceous beds. They were probably deposited in large deltas or estuaries, which were then being converted into dry land.

98. Subsequently to the great orogenic movements, which elevated and folded the Tertiaries, an oolitic limestone seems to have been formed on most of the Gulf islands; it consists of the remains of small foraminifera along with some sand, round which lime has been deposited in layers. It was probably a wind deposit and is identical

[1] Geol. Mag., decade V, Vol. II, July 1905, pp. 293—310.

with that of the Káthiáwár coast, which is known as "miliolite" and is of pleistocene age.

Of later date than the "miliolite" are the shelly conglomerates, which are found on all the coasts of the Gulf, and have been met with at an elevation of 450 feet. The shells which they contain invariably belong to species now living in the Gulf. With regard to many of the deposits here classed as recent or sub-recent, it is not unlikely that they are really pleistocene; but we have no means of determining their age exactly. The red sand-hills of the coast of Trucial' Omán are found for a distance of 8 miles or more inland; they owe their colour to numerous round grains of chert.

99. *Geological History of the Gulf.*—In the present state of our knowledge of this area it is impossible to trace the sequence of events prior to the great stresses which folded in the serpentinous basic igneous rocks of Maskat and 'Omán amongst the Carbo-Triassic beds. These movements probably occurred at the beginning of the Cretaceous. We may therefore date from this period the elevation of the mountain ranges of 'Omán. In the ocean-bed, whose southern limit was defined by these upheaved older rocks, were deposited the Upper Cretaceous beds of Hippuritic limestone which cover large areas in Persia. Following closely upon these and perhaps extending into the eocene period occurred the Hormuz series of volcanic flows accompanied by the formation of thick beds of salt and gypsum. It is not unlikely that shallow-water conditions prevailed here during part of this epoch, and some of the lavas and tuffs of the Hormuz series were probably formed beneath the water. After this period of volcanic activity occurred a great depression of most of Southern Persia, and within this depression the eocene rocks were deposited. This was accompanied by an upheaval of the volcanic area of the Hormuz rocks into dry land, which formed a barrier running in an approximately N.-W. and S.-E. direction, separating the eocene sea of Persia from that of Bahrain. It seems not unlikely that this land barrier continued through the upper eocene, oligocene and miocene, which appear to have been tranquil periods, the distribution of land and sea remaining almost unaltered except as demanded by the slight unconformities before the deposition of the Makrán series and the Bakhtiyári grits. In early pliocene times occurred the movements which produced amongst others the present mountain ranges of Persia. The actual Persian Gulf area seems to have been less disturbed than the Persian plateau, witness the almost horizontal strata of the Makráns in Hanjám, and the gently rolling

eocene rocks of 'Omán and Bahrain. It is on the whole likely that subaerial denudation continued over this area, and that the carving out of the topographical features to which the floor of the Persian Gulf and the Gulf of 'Omán owe their present contour was concluded during pliocene times. The limit of this land was doubtless determined by the steep submarine cliff, which runs along the Makrán coast and then, cutting across the Gulf of 'Omán, runs parallel to the Arabian coast. This feature may have been the result of a fault, but Mr. Pilgrim inclines to the idea that it was produced by the denudation of a gradually rising area during pliocene and possibly during pleistocene times. Then a wide-spread submergence took place, which buried fathoms deep the steep mountain-valleys, river-systems and sea-cliffs that were being carved out for so many ages previously. To movements of this nature we owe the deeply-cut inlets of Musandam and the islands dotting the Gulf, which are merely isolated peaks of the Hormuz volcanic series just rising above the surface of the water. The latest movement to which the Gulf has been or is now being subjected is one of gradual elevation, of which traces are found in recent littoral concretes, now as much as 450 feet above the present sea-level, and in the flat ledge which surrounds Maskat harbour. In the upper portion of the Gulf the deltaic deposits of the Tigris and Euphrates have contributed to this work of reclamation in an entirely different manner: within historical times these rivers have silted up their mouths to an extent which has materially altered the coast-line of this part of the Gulf, and in the future they are destined to unite Hassa to Fárs just as in the past they have produced the fertile plains of Mesopotamia.

THE FIELD-SEASON PROGRAMME, 1905-06.

100. The latter part of the year under report includes the first two months of the current field-season, and although several results of interest have already been reported, for the reasons given in the last Report,[1] it is inadvisable to estimate their real significance until the observations made have been appraised by further field-work and a critical examination of the materials collected. The field-work in progress includes the following:—

Assam:—Mr. R. R. Simpson is surveying the coal-deposits of North-East Assam and the Naga hills.

[1] *Rec. Geol. Surv. Ind.*, XXXII, 123.

Baluchistan:—Messrs. E. Vredenburg and G. H. Tipper are making a traverse of the Khelat and Las Bela States to complete the first reconnaissance of the Province.

Bengal:—Mr. K. A. K. Hallowes is examining the copper-bearing belt of Singhbhum in connection with the boring operations in progress.

Burma:—Mr. T. D. LaTouche is deputed to complete the general survey of the Northern Shan States; Mr. E. H. Pascoe for a survey of the oil-bearing areas, and Mr. J. M. Maclaren for an examination of the river-gravels.

Central India:—Messrs. C. S. Middlemiss, H. Walker, G. de P. Cotter and Sub-Assistant Sethu Rama Rau, surveying the unmapped areas westward from Bhopal.

Central Provinces:—Mr. P. N. Datta, mapping the areas previously unsurveyed in the Bhandára and adjoining districts.

Sind:—Sub-Assistant M. Vinayak Rao is in charge of the operations at Bukkur and Kotri for determining the silt discharge of the Indus River.

T. H. HOLLAND, *Director,*
Geological Survey of India.

CALCUTTA:
1st January 1906.

THE LASHIO COAL-FIELD, NORTHERN SHAN STATES. BY T. D. LATOUCHE, B.A., F.G.S., *Superintendent, and* R. R. SIMPSON, B.SC., *Mining Specialist, Geological Survey of India.* (With Plates 10 and 11.)

A REPORT by Dr. Fritz Noetling on this coal-field was published in the *Records* of the Geological Survey of India (vol. XXIV, pt. 2, p. 99) in 1891. At the time of Dr. Noetling's visit the river in which the only outcrops of the coal that are exposed occur, was in flood, and he could do little more than note the occurrence of the seams, and collect samples for analysis. Owing to the want of an accurate map it was also impossible to determine the position of the outcrops with respect to each other, and to discover whether more than one seam was represented.

The operations carried out during February and March of the year 1902 were confined to excavating all the outcrops that could be found, in order to measure the thickness of the seams exposed, and to fixing sites for borings, which were considered to be absolutely necessary for the purpose of determining the extent and value of the seams. A plane-table survey of the western portion of the field was made, on which the proposed sites were marked, and a copy furnished to the Engineer-in-Chief of the Burma Railways Company. Up to the present time, however, no borings have been put down, and our knowledge of the coal is confined to excavations made close to the outcrops.

The boundaries of the coal-field were mapped in 1903 by Mr. Datta and in the season 1904-05 Mr. Simpson was engaged during part of the time in making fresh excavations. He also discovered several previously unknown outcrops. During the same year the Railway Company also put in prospecting inclines at one or two points, with the object of testing the coal in bulk.

The coal-field lies in the upper part of the valley of the Nam-yau, one of the tributaries of the Nam-tu or Myitnge river, which drains the greater portion of the Northern Shan States. The southern border of the field corresponds very closely with the course of the Nam-yau, which flows from east to west about 5 miles to the north of Lashio, and with the 23rd parallel of north latitude. It lies east of longitude 97° 47′ (sheets 377, 378, 1 in.=1m., Upper Burma

Topographical Survey). The coal-bearing rocks extend along the north side of the river for about 15 miles, with an average width of about 4 miles. This area is covered with low, rounded grassy hills, rising to not more than 200 feet above the valley level, and separated by narrow strips of alluvium, usually occupied by rice-fields, which effectually cover up every outcrop of solid rock. The average height above sea-level is about 2,500 feet.

The low hills in the valley are composed of sandy clays and soft sandstones, of late Tertiary age and very easily disintegrated. A few bands, impregnated with oxide of iron, and slightly harder than the prevailing type, are occasionally met with, and these, with the exception of the coal, form the only outcrops of anything like solid rock in the whole field. Even these are solid only near the surface, where the ferruginous matter they contain seems to be concentrated. All the beds are extremely pervious to water, and when dug into break down at once into a sandy slush. A worse material for forming the roof and floor of coal workings could hardly be imagined, and since the coal seams all lie below the level of permanent saturation, there will be great difficulty in keeping the mines open.

The beds dip at low angles towards the north, where they are banked up against the barrier of older rocks, Palæozoic limestones and Mesozoic sandstones, which form the northern boundary of the valley. On the south, east, and west, these older rocks also appear from beneath the Tertiary clays, which thus occupy a well-defined basin. The coal appears to be confined to the lower portion of the latter series of beds, and its outcrops are therefore found only along the southern border of the field.

Outcrops of coal were observed at the following places:—

I. In the bed of the Nam-yau, half a mile west of the village of Hsunkwe, and about 1¼ mile north-west of the bridge on the cart-road from Lashio to Nam Hkam. An excavation in the bank enabled the following measurements to be taken :—

	Ft.	Ins.
16. Sandy clay		
15. Carbonaceous clay and coal (quickly thinning out)	6	0
14. Grey and yellow sand	6	0
13. Coal	3	0
12. Grey and yellow sand	8	0
11. Coal	13	0
10. Fire-clay		10
9. Coal	12	0

	Ft.	Ins.
8. Grey clay		6
7. Coal		9
6. Grey clay		8
5. Coal	2	0
4. Grey clay	28	0
3. Carbonaceous clay	2	0
2. Coal	5	6
1. Grey sandy clay		
Total	88	3

Dip—12° to 20° to N.10°W.

Excluding the two uppermost seams, which thin out within the limits of the section, the aggregate thickness of coal exposed here is 33 feet 3 inches.

An incline put in by the Railway Company 140 feet east of this outcrop, is 89 feet in length, and is driven towards the dip of the measures at an angle of 30°. Coal was struck at 52 feet from the start, but owing to the coincidence of the direction of the dip of the beds and the tunnel, little more than the top of the seam was proved until a vertical shaft was put down in the face. This reached a depth of 10 feet and was stopped in coal. The total thickness of coal proved was 23½ feet. In another similar incline, 450 feet to N. 88° E. the thickness of coal was found to exceed 17½ feet.

Besides these inclines, ten pits were put down in the neighbourhood of Hsunkwe, but owing to the water-logged condition of the ground, and the great thickness of the alluvial clays, only two were successful in reaching coal. No. 9 pit, 200 yards N. 50° W. of the village, on the right bank of a small stream, showed:—

	Ft.	Ins.
Soil and alluvium	12	7
Clayey coal (eroded)	3	5
Shale	3	6

Dip—20° to N.

No. 10, 228 feet N.10° E. of No. 9, showed:—

	Ft.	Ins.
Soil and alluvium	14	0
Thin bands of coal and clay (eroded)	4	6
Clay		5
Thin bands of coal and clay	1	6
Clay		5
Thin bands of coal and clay	1	11
Shale	2	9

Dip—15° to N. 20°E.

II. A small outcrop of coal occurs on the right bank of the Nam-yau, about half a mile above that west of Hsunkwe, and immediately above a sharp bend in the river. It is very close to the edge of the coal-field, the Palæozoic limestone cropping out on the opposite bank within sight of it. The coal here is of very inferior quality, and the whole "seam" is only 4 feet thick, consisting of carbonaceous clay with strings and nests of bright coal. The chief interest of this outcrop lies in the fact that both clay and coal contain the only fossils yet found in this coal-field. These are shells of gastropods, which appear to belong to the genera *Planorbis* and *Limnæa* but they are in so fragile a condition, and so greatly crushed, that they cannot be specifically determined. All that can be said is that they are probably of late Tertiary age.[1]

III. The next outcrops, proceeding eastwards, are found in the bed of a small tributary stream which joins the river a short distance above Napha, close to the point where the mule-road to the Kunlon ferry crosses the stream. Coal was found in four places along the bed of the stream. A pit sunk below the bridge showed:—

	Ft.	Ins.
Soil and alluvium	10	6
Soft sandstone with carbonaceous bands . . .	4	6
Hard coal	2	0
Coaly clay		10
Hard coal	1	4
Clay		4
Hard coal	1	0
Clay	2	6
Hard coal		4
Clay	3	0
	26	4

Dip—8° to S.-W.

Above the bridge three outcrops were found, but the upper and lower are mere bands of carbonaceous clay, 18 inches and 1 foot thick, respectively. The middle seam is 4 feet 6 inches thick, and contains fairly good coal. They all have a very slight northerly dip of about 3 degrees.

IV. The Naleng outcrop is situated at a sharp bend of the Nam-yau, due east of the village, and close to the Kunlon mule-road. The top of the seam only was visible in the bed of the river when Dr. Noetling visited the place, but an excavation on the right bank showed that

[1] Noetling, *Rec. Geol. Surv. Ind.*, XXIV (1891), p. 106.

the coal was 11 feet thick, resting on grey sandy clay. It was not possible to dig deeper than this, on account of the influx of water, but since the older sandstones, which form the floor of the valley, crop out in the bed of the river about 300 yards lower down-stream, it is unlikely that any lower seams occur here. The coal is quite horizontal where the excavation was made, but there are indications at the northern end of the outcrop in the river of a slight northerly dip.

An incline was put in by the Railway Company about 200 yards west of the outcrop, to a distance of 64 feet from the surface at an angle of slope of 20°, and was continued as a shaft for a few feet further. It was abandoned without reaching coal. Mr. Simpson also put down four trial pits over a line about half a mile in length near Naleng, but the alluvium was so thick that none of them succeeded in reaching coal.

V. A small outcrop was found in the bed of a small stream east of Naleng, about 400 feet above the road crossing. The seam is only 1 foot thick, with a steep dip to north. Numerous small fragments of coal were found about 100 yards further up-stream, but diligent search for their source was unsuccessful.

VI. On the right bank of the Nam-yau, at a point some 200 yards south-west of Winghtan, coaly sandstones are to be seen, but the appearances were not sufficiently promising to warrant prospecting operations.

VII. A coal outcrop occurs in a small ravine about a third of a mile north-west of the village of Mongpa, about six miles east of Naleng. A pit sunk here showed :—

	Ft.	Ins.
Soil and alluvium	8	2
Coal and clay	1	0
Sandy clay		5
Coal	1	5
Dirt		0½
Coal		7
Dirt		0½
Coal	1	7
Dirt		0½
Coal	2	0
Coaly shale		4
White shale	1	6
TOTAL	17	1½

Dip—15° to N. 23° W.

Traces of coal were also found in two places close to the village but were only a few inches thick.

VIII. The last outcrop was found in a small tank about 100 yards north-west of the village of Ta-yau, close to the eastern edge of the field. Only a foot of coaly shale is seen here, and a pit sunk close by through 13 feet of alluvium was abandoned without reaching coal.

IX. The only indication of coal on the north side of the field was found in a stream about a mile north-west of the village of Han-tau, 4 miles north-west of Mongpa. Fragments of coal were found in the stream, but their origin could not be discovered.

There appears to be little variation in the quality of the coal. It is a brown-black lignite with a semi-conchoidal fracture and a specific gravity of 1·53. It burns poorly in the open, with a dull flame and a sulphurous odour, and whilst burning decrepitates. As mined it is fairly hard and in largish lumps, but after a short exposure it breaks up into cubical fragments owing to the loss of moisture. In the following table are shown analyses of samples taken from the outcrops and from the inclines and pits:—

A.—Samples collected from outcrops.

	Moisture.	Volatile matter.	Carbon.	Ash.
Hsunkwe outcrop, seam No. 11 in section, p. 119.	19·84	35·72	34·84	9·60
Do. seam No. 2	18·04	40·16	30·60	11·20
No. II outcrop	19·78	32·02	28·64	19·56
Napha, 4 ft. 6 ins. seam	17·70	35·98	29·72	16·60
Naleng	17·76	35·64	37·40	9·20

It is to be regretted that the borings recommended in 1902 have not been put down. The Railway Company are said to have spent some 12,000 rupees on their inclines, but beyond obtaining bulk samples of the coal at Hsunkwe nothing has been done, whereas a few borings, probably costing nothing like the above amount, would at least have given some information about the continuity of the seams. The bulk samples might equally well have been taken from the outcrop at Hsunkwe, for the analyses show that the coal from the inclines differs

very little from that in the outcrop. It is also to be regretted that a bulk sample of the Naleng coal was not obtained, for the analysis shows that this is the best coal in the field. The result of the railway trials was very disappointing, and it may be assumed that the raw fuel is unsuited for locomotive purposes. Briquetting would cost at least Rs. 6 per ton, and this, added to a mining and transport cost of Rs. 5 per ton, would enable the briquetted fuel to compete with Bengal coal at Rs. 17-13, and wood fuel at Rs. 4-2 per ton at a total cost of Rs. 11 per ton. As the cost of wood fuel increases it is possible that the briquettes may come into use to a limited extent on that portion of the railway line between Lashio and Maymyo, but it is unlikely that it will ever command more than a small local market.

B.—Samples collected from excavations.

No.	Locality.	Depth in feet.	Section.	Ft.	Ins.	Moisture.	Volatile matter exclusive of sulphur and moisture.	Fixed carbon.	Ash.	Sulphur.	REMARKS.
			Eroded coal.	1	10						
			Coal		9						
			Coal and dirt bands.		6						
1	Hsunkwe, Ry. Co.'s No. 3 Incline.	18	*Coal*	3	10	18·94	37·62	29·61	13·83		
			Dirt		1						
			Coal		4						
			White clay		5						
			Coal	1	11						
			Dirt		1½						
2			*Coal*	4	5	22·95	35·10	27·62	14·33		
			Dirt		3½						
3			*Coal*	8	10	19·79	34·79	30·42	13·57	1·43	Seam not passed through. Sp. Gr. 1·53.
			Coal	3	0						
				26	4						

B.—Samples collected from excavations—concld.

No.	Locality.	Depth in feet.	Section.	ft.	in.	Moisture.	Volatile matter exclusive of sulphur and moisture.	Fixed carbon.	Ash.	Sulphur.	REMARKS.
4	Hsunkwe, Ry. Co.'s No. 4 Incline.	18	Eroded coal.	2	0						
			Coal	6	0	19·75	36·06	36·31	7·88		
5			*Coal*	7	0	20·04	36·65	29·72	13·59		This is the same seam as that in No. 3 incline.
			Dirt		1½						
			Coal	2	6						Seam not passed through.
				17	7½						
6	Hsunkwe, No. 10 pit.	14	Erosion plane								
			Thin bands of coal and clay.	4	6						
			Clay		5						
			Thin bands of coal and clay	1	6	19·15	23·96	17·13	39·76		In taking the sample the clay from the two five-inch bands was discarded.
			Clay		5						
			Thin bands of coal and clay.	1	11						
7	Mongpa, No. 1 pit.	10	*Coal*	5	8½	21·86	34·00	32·11	12·03		The seam contains three bands of dirt, each half-an-inch thick. These were discarded as much as possible, in taking the sample.

THE NAMMA, MAN-SANG AND MAN-SE-LE COAL-FIELDS, NORTHERN SHAN STATES, BURMA. BY R. R. SIMPSON, B.SC., *Mining Specialist, Geological Survey of India.* (With Plates 12 and 13.)

CONTENTS.

I.—THE NAMMA COAL-FIELD.

Situation, etc.

THE Namma coal-field is situated in the Hsenwi and Hsipaw divisions of the Northern Shan States. It is contained between latitudes 22° 36′—22° 55′ and longitudes 97° 42′—98° 2′, and extends within ten miles to the south-east of Lashio, the civil station of the Northern Shan States, and the terminus of the Mandalay-Lashio Railway.

The principal axis of the coal-field follows a N.-E.—S.-W. direction, and is about 15 miles in length. The average width is about 3½ miles, whilst the area contains some 50 square miles. A small outlier of the

coal-bearing rocks is found three miles to the south-west of the main area. It is about four miles in length, and probably not more than half-a-mile broad at the widest point. Its longer axis lies in the same direction as that of the larger area. The general elevation is from 1,500—1,800 feet above sea-level, and thus the area is sharply distinguished from the surrounding country, the average height of which is at least 1,000 feet greater, with summits exceeding 4,000 feet in height above sea-level.

The surface of the coal-field is composed of low, broken hills, intersected with numerous watercourses, and except for occasional plots of cultivated ground is covered with a dense growth of tree-jungle, offering considerable difficulty to prospecting operations. The drainage is received by the Nam Pawng river, which traverses the field from end to end, and is joined on its left bank by the Namma, a river which flows from the east, and crosses the south-western end of the coal-field. Below the confluence the joint streams are known as the Namma river.

The largest villages within the area are Mansé (22° 48′—97° 56′), on the north-east, and Namma (22° 43′—97° 53′), on the south-west, from the latter of which the coal-field derives its name. The main road from Lashio to Tangyan crosses the coal-field some 6 miles from the south-western end. It is provided with wooden bridges, but is unmetalled, and consequently traffic can only be carried on with difficulty during the rains.

The climate during the winter is salubrious, but from the break of the rains in June until almost the end of the year it is very feverish.

The coal-field was visited and reported on in 1890 by Dr. Noetling,[1] Geological Survey of India. Although he actually found only two seams, of three and six inches, respectively, in thickness, he was so bold as to hazard the opinion that there are at least ten coal seams, none of which is less than five feet thick.

During the field-season 1902-03, Mr. P. N. Datta,[2] also of the Geological Survey of India, visited the coal-field. He has recorded the finding of a coal-outcrop from 10 to 12 feet thick at a point about one mile east of Namma, and also two or three outcrops of thin coal-seams in the hilly ground about half-a-mile south-west of Namma.

[1] *Rec., G. S. I.*, Vol. XXIV, pt. 2, p. 116.
[2] *Mss., Geol. Surv. India.*

Geology.

The general geological features of a large portion of the Northern Shan States have been worked out chiefly by Mr. T. D. LaTouche,[1] Superintendent, Geological Survey of India, but as the relations of the rocks found within the area under discussion are not yet fully established, no definite group-names have been adopted throughout this paper.

The rock formations found within the area under discussion are :—

Age.	*Character.*
4 Recent.	Clays and conglomerates.
3 Pliocene ?	Clayey shales, sandstones, conglomerates and coal-seams.
2 Doubtful.	Hard, purplish sandstones.
1 Earlier Palæozoic.	Blue and white limestones.

The disposition of these rocks within the field can be understood by reference to the geological map (Plate 12), which was prepared whilst the prospecting operations were in progress.

Earlier Palæozoic.—This formation is the lowest seen within the area. It forms the basement upon which the younger rocks have been deposited, and, except on the east, where rocks of undetermined age intervene, forms the boundary of the coal-field. It consists of hard, blue or white limestone, occasionally shaly, but, as a rule, possessing a massive character. It has been extensively folded along an axis roughly coinciding with the longer axis of the coal-bearing rocks, and as a consequence of this folding the limestone has been in many places severely crushed, the particles having been subsequently re-cemented by calcite.

Rocks of doubtful age.—These rocks are only seen on the east of the coal-field, where they consist entirely of hard, thin-bedded, much-jointed sandstones, purplish in colour. They appear to be unconformable to the limestone. Their direction of dip varies from north to north-east, usually at an angle of about 30°.

The Tertiary beds.—It is in these rocks that the coal-seams occur. They consist of soft, whitish-yellow to light-brown, clayey shales—amongst which the coal seams are interbedded—soft, white or yellow sandstones and conglomerates. The latter are made up of boulders of yellow quartz, quartzite, and crystalline rocks, including a

[1] Annual Reports, G. S. I., 1899—1903.

granite. They were considered by Dr. Noetling[1] to be of recent alluvial origin, but in the Nampawng river section, they are well-shown between Suplaw and Namma and undoubtedly form an integral part of the Tertiary rocks, conforming absolutely with the latter in amount and direction of dip.

The fossils which have been found within the beds correspond closely with existing species, and from this fact it has been inferred that the rocks are of pliocene age. As regards the respective proportions of these rocks which make up the whole it is, in the absence of anything like continuous sections, difficult to form an estimate. It can, however, be stated generally that the shales are by far the most prominent, the conglomerates coming next, whilst the sandstones are nowhere largely developed. As a general, but not invariable rule, the coal-seams are found close to the boundary of the field, and were it not for the possibility of overlap it might be concluded that they occur near the base of the group. The direction of dip varies from north-west on the south to north-east at the north-eastern end of the coal-field, the average angle being about 20°. Both in direction and amount, however, there is considerable local variation. In most cases, as Mr. LaTouche has pointed out, this is probably due to underground denudation of the limestone floor, but occasionally, contortion of the rocks, due to folding agency, can be observed. As far as can be judged from the meagre exposures of the rocks which occur, the southern boundary of the coal-field appears to be perfectly natural. For quite two miles from the northern boundary no exposures of the rocks are to be found. It is, therefore, not easy to say whether the coal-field is an area of original deposition, as appears likely, or is merely a fragment of once extensive area, let down by faulting, and preserved from the denuding agencies which have swept away the adjacent portions. It seems probable, however, that the Tertiary rocks have been deposited in a pre-existing erosion channel in the older rocks, and that they have subsequently been tilted by a continuance of the folding movement.

Recent deposits.—These consist of clays and conglomerates. The latter are derived from the disintegration of the Tertiary conglomerates, and are most prominent in the bottoms of the valleys, where they form beds up to ten feet in thickness. When present they invariably

[1] *Op. cit.*, p. 118.

underlie the clays. The clays have a reddish-brown colour and are found covering the whole of the area. They have been formed chiefly from the disintegration of the rocks *in situ*. In the lower ground they have naturally accumulated to a greater extent, and occasionally are found to have a thickness of not less than 30 feet.

Details of coal-outcrops and excavations.

In the Lashio coal-field nearly all the outcrops of coal which are of importance are to be found in the bed of the river which traverses that area. The very reverse is the case in the Namma coal-field, for although excellent sections of the shales, conglomerates, etc., are to be seen in the banks of the Nam Pawng river, yet the outcrops of coal visible are few and unimportant. In the higher ground, however, where the surface is frequently rugged, and the streamlets have a fairly rapid fall, the alluvial capping has, in many places been washed away, and outcrops of coal exposed, Many of these outcrops have been found, but, owing to the difficulty attending the examination of country so jungle-clad, and the presence, in streams flowing from the limestone, of a thick coating of calcareous tufa, it is probable that as many, if not more, have escaped notice. The localities in which coal has been found are shown roughly on the map of the coal-field (Plate 12).

Coal near Namma village:—The position of coal-outcrops lying within a mile and a quarter of Namma is shown in some detail on the sketch-map,[1] on a scale of 1,600 feet to 1 inch (Plate 13).

Commencing on the south-west, coal is first seen at a point about ½ mile east of Nakun and 1½ mile south-west of Namma. The outcrop is seen on the path connecting the two villages and at the crossing of the large stream which flows to the Namma river *viâ* Nakun. In the bed of the stream the seam appears to be about 4 feet in thickness, whilst about 50 feet further down a coal-seam about 12 inches thick can be seen. The dip of the rocks is to N.W. at 20°. The coal is hard, bright and of good appearance. At a distance of 40 feet from the stream a pit was sunk, the section being:—

	Ft.	Ins.
Alluvial clay and pebbles	12	0
Grey shale	1	0
Coal with shaly parting, 1" thick	1	10
Shale		3

[1] The map is based upon a theodolite-survey. For its main outlines I am indebted to Mr. F. Farndale-Williams of the Burma Railway Company, who visited Namma whilst the work of exploration was in progress.

A heavy influx of water caused a partial collapse of the excavation, and time did not permit the sinking of a second pit. It is probable, however, that there is more coal below.

About a three-quarters of a mile south-west of Namma the outcrops of two coal-seams are exposed in the tributaries of a stream flowing north. The dip of the rocks is to N. 40° W. at 25°, and the two seams are separated by shales some 25 feet in thickness. The outcrops can be traced in the adjoining streamlets for some three or four hundreds of feet on either side. Three pits were put down, the sections of the rocks being :—

Lower Seam.

No. 2 pit.	Ft.	Ins.
Soil and clay	6	0
Coaly shale	3	6
Shaly coal	2	0
Shale	1	0

Upper Seam.

No. 1 pit.	Ft.	Ins
Soil and clay	5	0
Sandy shales	4	0
Hard, bright coal	1	4
Clay		4
Hard, bright coal	1	10
Slightly coaly shale		8

No. 3 pit.	Ft.	Ins.
Soil and clay	5	0
Shale	2	0
Hard, bright coal		10
Clay		2
Hard, bright coal with clay band ½" in thickness .		11
Shale	1	0

On the opposite side of the watershed, and about ½ mile south-west of No. 3 pit a seam of poor coal, about 2 feet thick, outcrops.

Some 200 yards east of No. 3 pit, a seam of coal, 4 inches thick, was found outcropping in the bed of a small streamlet.

About half a mile north of No. 3 pit, and rather more than that distance to W.S.W., of Namma coal débris is very prominent in a stream flowing E.N.E. The dip of the rocks is to N. 30° W. at 18°, and consequently the strike coincides roughly with the direction of the nala.

Coal is exposed in several places, but careful examination proved that there is only one coal-seam. An average section of the seam is:—

	Ins.
Hard, bright coal	4 to 7
Soft shale	6
Hard, bright coal	7

The shale overlying the seam is crowded with fossil shells of species strongly resembling existing types.

No. 4 pit lies about half-a-mile S.S.W. of Namma, and about 100 feet west of the path leading from Namma to Nammawhsom. At this point an outcrop of coal was found covered with calcareous tufa to a depth of two inches. The pit was sunk to a depth of 10 feet in rock débris without reaching coal. It is probable that the coal seam is denuded at this point. Incoming water prevented further sinking.

Coal is found outcropping in a stream at a point 900 feet south of Pengshai. The dip of the rocks is N. 40° W. at 35°. The section measured in pit No. 5, which was put down here, is:—

	Ft.	Ins.
Surface soil and clay	6	0
Soft, clayey coal		9
Soft, coaly clay		6
Soft, clayey coal	2	3
Shale	2	0

Some 400 feet further up the stream coal, 9 inches thick, can be seen.

No. 6 pit is situated in an orange grove at a point about 1,000 feet south-east of Pengshai. It passed through about 18 inches of hard, bright coal.

On the right bank of the Namma river, close to Nanan, and some 1,800 feet east of Namma, several seams of coal are to be seen in very disturbed ground.

The first outcrop is 14 inches thick, and dips to the east at an angle of 36°. At a point 80 feet down-stream a second coal-seam, 18 inches thick, dips north at an angle of 44°. Some 50 yards further on what appeared to be the outcrop of a thick seam of coal was discovered underlying a thickness of 20 feet of alluvial conglomerate and clay. A side-cutting (Trench No. 19), 80 feet in length, was made, proving the occurrence to be most irregular. The coal seam appears to be from three to four feet in thickness, and has been dislocated by a fault with a throw of about four feet. In the dry bed of a stream close to this

point the same coal-seam outcrops. Pit No. 7 was sunk here, the section passed through being:—

	Ft.	Ins.
Poor coal	1	0
Dark shale with lenses of bright coal	2	0
Coal and shale bands	2	10
Hard, bright coal	1	10
White, clayey shale	1	0

On the opposite wall of the shaft the section is quite different, although similar in the aggregate. On the side on which the section was measured the dip is to south-west at 30°, whilst on the other side the rocks are horizontal.

The outcrops of the best coal-seam which has been found within the area are to be found on the hilly ground about a mile to the east of Namma. Over a distance of 2400 feet seven pits and cuttings were made, the sections and dips revealed being as follows:—

No. 8 pit.	Thickness.	
	Ft.	Ins.
Surface soil, etc.	5	0
Sandstone with coaly bands	4	0
Bands of hard coal and clay	1	6
Bright, hard coal		6
Bands of hard coal and clay	3	0
Bright, hard coal	3	0
Bands of hard coal and clay	1	0
Shale	1	0
Dip—W. at 24.°	19	0

No. 9 pit.	Vertical measurement.		True Thickness.	
	Ft.	Ins.	Ft.	Ins.
Surface soil, etc.	3	0	1	11
Clayey shale	7	0	4	6
Weathered coal	3	0	1	11
White, clayey shale	1	4		10
Bright, hard coal	9	0	5	9
White, clayey shale		3		2
Bright, hard coal	2	0	1	3
White, clayey shale		2		1
Bright, hard coal	7	0	4	6
White, clayey shale	1	0		8
Bright, hard coal	1	0		8
White, clayey shale	1	0		7
	36	0	22	11

Two or three thin, irregular clay-bands besides those mentioned above occur.
Dip—N.55° W. at 50.°

Cutting No. 10.

	Ft.	Ins.
Hard, bright coal	9	0
Coal of shaly appearance	2	6
	11	6

A fault with throw of 3′ 6″ was proved in the cutting.
Dip—W. at 10°.

Pit No. 12.

	Ft.	Ins.
Surface soil, etc.	5	0
Yellow shale	1	0
Grey shale with coaly strings	3	0
Bright, hard coal	11	10
Soft, shaly coal	1	0
White, clayey shale	2	6
	24	4

Dip—N. 20° W. at 25°.

Pit No. 13.

	Ft.	Ins.
Soil	1	0
Soft, white sandstone	1	0
Weathered coal	1	0
Hard, bright coal	13	0
Shale		3
Hard, bright coal	3	8
White, clayey shale	3	0
	22	11

Dip—N. 50° W. at 13°.

Cutting No. 14.

	Ft.	Ins.
Surface soil, etc.	7	0
Burnt clay	4	0
Poor, crushed coal	7	0
Clayey shale	3	0
	21	0

The coal seam has evidently been on fire at this point.
Strike—N. 55° E. Dip—90°.

Cutting No. 15.

	Ft.	Ins.
White sandstone	9	0
Hard, weathered coal	7	0
Clayey shales	13	0
Sandstone and coal bands	6	0
	35	0

Dip—NW. at 66°.

From the section revealed in No. 8 pit it appears that this coal-seam depreciates in both quality and thickness towards the west, and it is quite probable that the seven feet seam, outcropping near Nanan and proved by No. 7 pit, represents the same seam in a still more impoverished condition. On the east, as seen in cutting No. 15, the rocks are highly disturbed, and although careful search was made beyond the last-mentioned excavation no continuation of the seam was found.

At a point some 1,000 feet north of No. 8 pit outcrops of a thin coal-seam were found in several places. Near the best of these exposures No. 11 pit was put down, the section revealed being :—

	Ft.	Ins.
Surface soil and clay	6	0
Coaly clay		4
Clay		6
Coaly clay		2
Clay		6
Clayey coal		2
Clay		8
Clayey coal with streaks of bright coal		2
Grey clayey shale	1	3
	9	9

Dip—W. at 5°.

In a stream at a point about 500 feet north-east of No. 11 pit a seam of hard coal, 20 inches in thickness, outcrops. Some two hundred feet further down this stream a seam of coal, about one foot in thickness can be seen in two places. The dip of the rocks in this neighbourhood is to north-west at an angle of 28°.

Pits Nos. 16 to 18 are situated about 2,000 feet to the north-east of trench No. 15. They were put down on the outcrop of a seam of hard, bright coal of rather more than one foot in thickness. The dip of the beds in the vicinity is to north-west at an angle of 39°.

Coal near Möng Ting village.—Outcrops of coal were found in the banks of the Namun stream at a point about half-a-mile north of Möng Ting (22°47′-97°54′). The positions of these occurrences are clearly shown on the map (Plate 12) and on the wood-cut (Figure 1). There are two groups of outcrops, lying some 1,600 feet apart. Those on the east are found within a space of 500 feet, and over this distance four trial pits were sunk, and the following exposures made :—

Pit No. 1.	Ft.	Ins.
Surface clay, etc.	7	0
Pebble conglomerate	1	6
Coal and clay bands		5
Clay with occasional coaly nests and strings.	9	0
Hard coal	1	10
Clay	1	2
Clay and coal bands	3	6
Hard coal	3	5
Coaly shale with fossil shells.		5
Coal	1	2
White clay	3	0
	32	11

Dip to North at 25°.

Pit No. 2.	Ft.	Ins.
Surface clay, etc.	6	2
Pebble conglomerate	1	4
Clay	3	8
Hard coal	5	8
White clay		5
Coal		2
White clay	1	4
Coal and clayey coal		10
Clay		3
Coal		5
White clay		6
	20	9

Dip to N. 15° W. at 20°.

Pit No. 3.	Ft.	Ins.
Surface clay, etc.	5	0
Eroded coal seam	1	0
White clay	1	6
Coal		8
Clay		2
Coal		3
Clay		3
Coal		2
Clay with occasional thin bands of coal.	3	9
Poor coal	2	0
White and grey clays	3	9
Coal		8
Clay		7
White clay with coaly streaks	1	0
	20	9

Dip to N. 18° W. at 16°.

Pit No. 4.	Ft.	Ins.
Surface clay	6	0
Shales	11	0
	17	0

Outcrop of coal seam under two feet of water in stream.

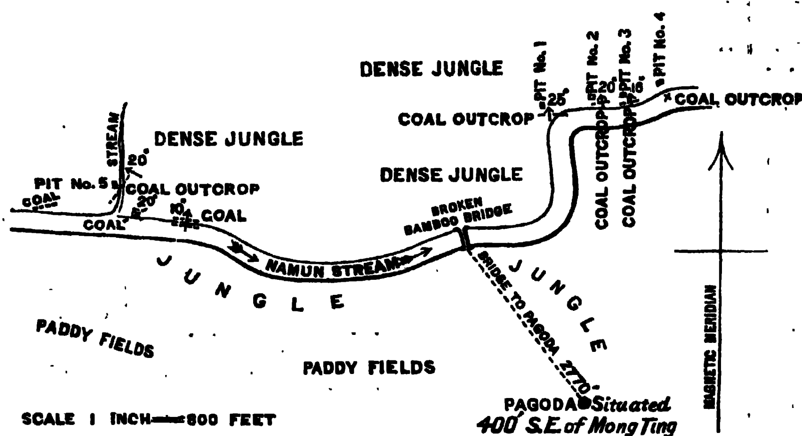


FIG. 1.—*Map showing position of coal outcrops and exploring pits near Möng Ting, Namma Coalfield.*

In No. 4 pit the influx of water was so great that the appliances available were insufficient to cope with it, and the sinking was abandoned.

The western coal outcrops are found over a distance of about 600 feet. Going up-stream coal is first seen, under several feet of water, near the left bank. At the same place, but about 15 feet above the water level the following section was measured :—

	Ft.	Ins.
Coal	1	3
Shale		4
Coal		4

This seam can be traced for about 40 feet, in which distance the upper coal band thins to 10 inches. At a point some 50 yards further up, a thin band of sandy shales with coaly strings is to be seen. Still 30 yards further on the following rocks are to be seen :—

	Ft.	Ins.
Coal	1	3
Sandstone		10
Coal		10
Shale		—

In the bed of a streamlet at a point 140 feet north of the outcrop last mentioned, coal is found outcropping. No. 5 pit was put down here, the rock-section revealed being:—

	Ft.	Ins.
Surface clay, etc.	6	6
Pebble conglomerate	1	8
Clay	1	8
Coal and clay bands	1	2
Clayey coal	2	0
Hard coal	3	0
Shell band		4
Coal		6
Shale		3
Coal		10
White clay		3
Coal		7
White clay	2	0
	20	9

The dip of the rocks is to N70°W at an angle of 20°. The section is not unlike that found in No. 1 pit, and it is probable that the two outcrops are of one and the same coal-seam.

Perhaps 100 feet above the point where the small stream, upon which No. 5 pit is situated, meets the main stream a seam of coal, 18 inches thick, overlaid by shale, can be seen in the river bank, dipping vertically. The high dip is probably due to slipping of the bank. At a point about 100 yards above this occurrence a 6-inch coal-seam, overlaid by 8 feet of shale containing thin coaly bands, outcrops.

Coal near Mansé.—Several unimportant outcrops of coal are to be seen on the right bank of the Nam Pawng river near Mansé. Going up-stream the first outcrop of coal is from ½" to 1" in thickness, and is to be seen at a point about 100 yards below the foot-bridge. Close to the foot-bridge a seam of bright coal, 14 inches thick, outcrops in the river bank under some inches of water. At a point a little south of Hpa-so, and about ¾ mile north-east of Mansé coal is found outcropping in two places about 100 feet apart. The measured sections are:—

	Ft. Ins.		Ft.	Ins.
Shale	—			
Coal	3½	Coal		1
Shale	2½	Shales	5	0
Coal	6	Coal		4

Coal in the rocks of the south-west outlier.—No coal was found, *in situ*, in the rocks of this small area. At a point ½ mile west of Kong-pau (22°40′ – 97°47′) three pieces of drift coal, the largest 12 inches square, were seen lying on a river-beach. Although no fragments of coal were seen for some miles above this point it is yet possible that these pieces of coal were derived from the Namma outcrops.

At a point some 800 feet from the river and 1½ miles due west of Pang-nga a piece of float coal was found in a stream. It measured 6″ × 2″ × 2″, and was thickly coated with calcareous tufa. The locality is high above the river, and it is likely that the coal is derived from a coal-seam in the vicinity. No outcrop was, however, found.

Quality of the coal.

The coal of the Namma coal-field is a lustrous lignite with a specific gravity of 1·37. In colour it is a bright black, and the streak is brown. It is non-coking and appears to be free from any large intermixture of iron pyrites. It is very hard, but brittle, displays little or no cleavage, and breaks with a conchoidal fracture. It is difficult to mine, owing to its splintery character, but, being well-jointed, the exercise of a little skill on the part of the workman, enables it to be broken in large slabs. On exposure to the atmosphere it loses moisture, becoming much lighter in weight, and breaks up into irregular cubical fragments.

As can be seen from the table of analyses given below, the coal is very low in carbon, and the percentage of moisture and volatile products is very high. The only redeeming feature it possesses is the smallness of the ash content.

Table of Analyses.

No.	Locality.	Depth in feet.	Section.	Ft. Ins.	Moisture.	Volatile matter exclusive of moisture and ash.	Fixed Carbon.	Ash.	Sulphur.	REMARKS.
1	No. 1 pit, ½ mile S.-W. of Namma.	9	*Coal*	1 4	15·57	26·55	25·97	31·91		
			Clay	4	...	...	...	...		
2			*Coal*	1 10	6·04	37·99	20·06	35·91		

No.	Locality.	Depth in feet.	Section.	Ft.	Ins.	Moisture.	Volatile matter exclusive of moisture and ash.	Fixed Carbon.	Ash.	Sulphur.	REMARKS.
3	No. 2 pit, ½ mile S.-W. of Namma.	6	Coaly shale	3	6	...	...	..	...		
			Coaly shale of better quality	2	0	12·90	8·37	9·61	69·12		
		9	Bands of coal and clay.	1	6						
4	No. 8 pit, about 1 mile E. of Namma.		Coal	0	6	} 10·65	21·32	17·90	50·13		
			Bands of coal and clay.	3	0						
5			*Coal*	3	0	11·84	42·16	39·05	6·95		
			Bands of coal and clay.	1	0	...	...	...	...		
		10	Weathered coal.	1	11	...	...	...	...		
			White clay		10	...	...	...	...		
6	No. 9 pit, about 1 mile E. of Namma.		*Coal*	5	9	17·81	36·09	38·29	7·81		
			White clay		2	...	...	...	...		
			Coal	1	3						
7			White clay		1	} 16·37	34·99	38·53	10·11		
			Coal	4	6						
			White clay	0	8	...	...	...	...		
			Coal	0	8	...	..	...	..		
8	No. 12 pit, about 1 mile E. of Namma.	9	*Coal*	11	10	18·16	34·96	38·39	7·66	0·83	Sp. Gr. 1·39.
			Shaly coal	1	0	...	...	...	...		

No.	Locality.	Depth in feet.	Section.	Ft.	Ins.	Moisture.	Volatile matter exclusive of moisture and ash.	Fixed Carbon.	Ash.	Sulphur.	REMARKS.
9		2	Weathered coal	1	0	...	...	...	...		
10	No. 13 pit, about ¼ mile E. of Namma.		*Coal*	7	0	17·83	37·38	39·96	4·83		
			Coal	6	0	12·73	40·25	38·87	8·15		
			Shale	0	3	...	...	...	...		
			Coal .	3	8	...	...	...	...		
11		10	Coal and clay bands	1	2	...	...	...	...		
12	Möng Ting No. 5 pit.		*Clayey coal*	2	0	11·34	24·26	18·99	45·41		
			Coal	3	0	13·70	39·56	33·44	13·30		
13	Möng Ting No. 1 pit.	21	Coal and clay bands	3	6	...	...	...	...		
			Coal	3	5	16·32	37·40	33·25	13·03		
			Coaly shale	0	5	...	...	...	...		
			Coal	1	2	...	...	...	...		
14	Möng Ting No. 2 pit.	...	*Coal*	5	8	18·16	38·87	31·18	11·79		

In an open fire the freshly-mined coal burns well, with a bright flame, only a reasonable amount of smoke and a somewhat aromatic odour.

The quality of the coal is distinctly superior to that of any of the coals from other coal-fields in the Northern Shan States, but at the best it is a poor fuel, and, unless briquetted, will be of little value for locomotive purposes.

In November last a locomotive trial of coal from the neighbouring Lashio coal-field was made on the Lashio-Maymyo branch railway under the direct supervision of some of the chief engineering officials of the Burma Railway Company. It appears to have resulted in complete failure, for it was found necessary to revert to the use of wood fuel in order to enable the locomotive to get back to the starting-point.

Recently a consignment of about seven tons of Namma coal was carted to the railway for trial. Although there was reasonable ground for hope that, in this case, a better result would be achieved, yet the Locomotive Superintendent was only enabled to report that "when freshly-mined and burned with a strong draft, it does fairly well and would suit stationary boilers, but it is quite unfit for a locomotive engine fuel."

Economic features.

So far as is at present known, there are only two coal-seams of economic importance in the Namma coal-field. The seams in question are the thick seam east of Namma, and the Mŏng Ting seam. As the latter is of somewhat inferior quality it may be left out of count for the present.

The Namma seam has been proved over a length of outcrop of about 2,400 feet. It varies in thickness from about 7 to 17 feet, and is variable also in quality. By no means sufficient prospecting work has yet been done to enable an authoritative opinion to be given as to the amount of coal available. Assuming, however, that a thickness of ten feet of coal is workable over a length of outcrop of 1,500 feet and that mining could be carried on to the moderate distance of 1,000 feet from the outcrop, the amount of coal available would be rather more than half-a-million tons.

The only consumer of the coal would be the Burma Railway Company on whose line, between Lashio and Mandalay, the coal would enter into competition with wood fuel costing Rs. 4-2 per ton and Bengal coal costing Rs. 17-13 per ton. I am uninformed as to the actual amount of fuel used on this branch, but it is probably not a large amount; perhaps 15,000 tons.

The geographical position of the coal relative to the railway is unfortunate, for at the nearest point it is not less than 19 miles distant in a direct line across country, from the railway line. The distance by cart-road from Lashio railway-station would be about 25 miles, and there is an unmetalled cart-road already constructed for about two-thirds of this distance. Presuming that a cart-road were in existence the cost of cartage would certainly not be less than Rs. 10 per ton. Adding to this the cost of mining the coal, say, Rs. 4 per ton, and also a charge for briquetting of Rs. 6 per ton, the total cost is seen to be Rs. 20 per ton. It appears therefore, that with cart transport even neglecting the briquetting cost, there is no hope of the fuel being able to compete on anything like equal terms with the superior foreign article.

At first sight it would appear that the cheapest method of marketing the coal would be to float it down the Namma river to a depôt on the railway-line at Se-en. Even in the dry season of the year there is a considerable volume of water in the river, but there are unfortunately numerous bars and rapids, and for about ten miles the stream races through a deep and narrow gorge in which no boat could live. Even supposing that these natural obstacles did not exist, the flooded condition of the river during half the year would preclude navigation.

These methods of transport being out of the question there remains the question of a railway line to be considered. Perhaps the best alignment would commence at a point on the main line about 7 miles due west of Nawng Mawn (22° 46′-97° 41′), and would run nearly due east, through a break in the range of hills, to a point about 3 miles west of Man Pyen (22° 47′; 97° 50′), from whence it would pursue a south-easterly direction to the presumed coal-mine near Namma. Such a line would be about 30 miles in length. It would necessitate the bridging of two considerable rivers, the Nam Yan and the Nam Pawng, and even for a two-foot gauge, the cost would probably not be less than 30 lakhs. It can be definitely asserted that the present prospects of the coal-field do not warrant the expenditure of anything approaching this amount of money.

Telpherage or wire-rope transmission might be practicable, but here, again there is reason to fear that the expenses of operating a line not less than 20 miles in length would be prohibitive.

I would, however, strongly recommend that before any attempt be made to provide means of communication further prospecting operations should be undertaken, and vigorous efforts made to prove a much larger quantity of coal than I have been able to prove during the five or six weeks which I spent on the ground. Attention should be confined to tracing the outcrops of the two workable seams by means of shallow borings and pits. This being accomplished, a line of three or four borings, put down at points situated about 1,000 feet from the outcrop towards the dip of the rocks, should enable a competent mining engineer to come to a definite opinion as to the value and possibilities of the coal-field.

Should it be eventually decided to commence mining operations, it will be found that the winning of the coal will present certain serious difficulties which, however, under skilful management, could undoubtedly be overcome. The difficulties referred to will be the steepness of the angle at which a large portion of the coal-bearing

rocks are lying, the softness of the rocks enclosing the coal seam, the fact that the recovery of a large portion of the coal will necessitate heavy pumping operations, and the absence of a suitable supply of labour locally.

The estimated half-million tons of coal referred to on a previous page lies above the level of the rivers which drain the coal-field, but there is little doubt that a large quantity of water would percolate into the mine-workings from the numerous water-courses which flow over the surface. In order to reduce this amount to a practicable minimum it would be imperative to leave unworked an outcrop barrier of not less than 150 feet of coal.

Although shafts would be preferable in many ways, there would be no serious objection to opening out the workings by means of inclines from the outcrop, provided that the latter were commenced from suitable positions, and lined to prevent percolation of water.

The mode of working most suitable would be the ordinary *bord and pillar* method with such modifications as experience might suggest.

Labour would be a serious expense. The Shans, although a charming race socially, and physically fitted for labour, are contemptible as workmen. Owing to the fertility of the soil, they have abundance of food and raiment, and comfortable houses wherein to dwell. Under these conditions they lead a contented life, and perhaps, wisely, fail to see the necessity for hard labour. The one thing they lack is ready money, and in order to supply this deficiency they will condescend to do a very moderate amount of work at double the rates of pay prevailing in India. To work on two consecutive days would appear to them to be mere foolishness, and besides this every fifth day they must attend the nearest bazaar in order to hear the news, and enjoy a friendly pipe with acquaintances from neighbouring villages. Except for light tasks, the Shans must be left out of count in the recruiting of a labour force.

During the construction of the railway, I am informed that 98 per cent of the labour was performed by natives of India, imported for the purpose, and Chinese from across the Yunnan border. The latter are hard-working, excellent workmen, and very amenable to discipline when treated with discretion. Practically all the ancient mines in Burma and the Shan States were worked by the Chinese, and as a race they appear to possess a natural aptitude for mining

operations. Should the Namma coal-field ever be exploited there is little doubt that Chinese labour would be the most satisfactory and probably also the cheapest.

II.—THE MAN-SANG COAL-FIELD.

Introduction.

This coal-field is situated in the neighbourhood of Man-sang (22° 26′; 97° 57′), a village lying 7½ miles due west of Möng Yai, the most important village in the South Hsenwi division of the Northern Shan States and the place of residence of the reigning Sawbwa of S. Hsenwi. The northern end of the area lies sixteen miles S.S.E. of the south-western end of the Namma coal-field.

The extent of the known area is 13½ square miles, but as the boundary on the south and south-east is ill-defined, the coal-field may be of greater extent than appears to be the case.

The region is one of low, rolling hills with an average elevation of 2,800 feet. These are for the most part covered with grass, but patches of timber are by no means uncommon. For many miles to the south and south-east the same topographical features prevail, but on the north are found hills rising to a height of 4,500 feet above sea-level. The drainage is effected by numerous, small streams which converge to form the Namsang, a stream which flows into the Nam Lawng river at a point five miles south of Man-sang.

Within the area there are no roads, but the unmetalled cart-road from Lashio to Tangyan passes within three miles of the north-eastern boundary of the coal-field.

During the course of his economic survey of the Northern Shan States, in 1890, Dr. Noetling apparently passed through the coal-field. In his report[1] he mentions the occurrence of "a few beds of black, coaly shale."

Geology.

Although no fossils were discovered, the age of the coal-bearing rocks is undoubtedly the same as those of the Lashio and Namma coal-fields, *i.e.*, late Tertiary, probably pliocene. The geological features bear considerable resemblance to those of the above-mentioned coal-fields. The essential

[1] *Rec. Geo. Surv. Ind.*, vol. XXIV, pt. 2, p. 112.

difference is the presence of dolerite,[1] which forms lofty hills to the north, and occurs irregularly within the coal-field. Its relation to the Tertiary rocks is not apparent. No distinct evidence of intrusion was observed, and it may be that the coal-rocks were laid down on an irregular surface of the dolerite, portions of which have been exposed by denudation. In an exposure resembling an intrusive dyke the dolerite was found to be distinctly amygdaloidal, a structure not commonly observed in intrusive rocks. The basement rock is the well-known Palæozoic limestone, exposures of which are to be found in numerous places along the western boundary. The recent deposits are chiefly of clay, but they include a conglomerate of dolerite boulders which is very prominent for about three miles from the northern boundary. On the south and south-east the mantle of alluvial deposits is so thick that none of the streams appear to have cut down through it. Although several traverses were made, in different directions, across this ground no exposures were found nearer than the Nam Lawng river on the south, and its principal tributaries on the east, a distance of 4½ miles from the nearest outcrop of the coal-bearing rocks. The rock exposed in these places belongs to the Maymyo limestone formation.

The coal-bearing rocks are chiefly composed of yellow, white or grey shales, with coal seams. The shales are occasionally sandy, and in one place a thin band of sandstone was found. The dip is inconstant. On the south it varies from north-west to north-east at an average angle of 15°. As the northern boundary is approached it alters to south-west and south at 30°. Close to the boundary it is again northerly, at angles of from 30° to 50°.

[1] I am indebted to Mr. LaTouche for the following description of specimens of the dolerite:—

No. I. Sp. Gr. 2·82. Dark grey, compact, fine-grained matrix with numerous larger crystals of felspar. The ground-mass consists of a mixture of minute plagioclose felspars and granular augite, with patches of devitrified glass, sometimes showing a well-defined spherulitic structure. The larger felspars and augites are much corroded (schillerized). The felspars give extinction angles up to 28° and are probably labradorite. There is a fair amount of iron present.

No. II. Sp. Gr. 2·54. Dark grey amygdaloid. The ground-mass consists of minute felspar needles and granular augite set in an opaque matrix, probably glassy. There are a few lath-shaped crystals of plagioclose felspar, with high extinction angles, probably labradorite.

Coal outcrops and excavations.

Owing to the irregularity of the dip it is not easy to estimate the number of coal seams within the field. They appear, however, to be numerous, but they are chiefly thin, no seam exceeding four feet in thickness.

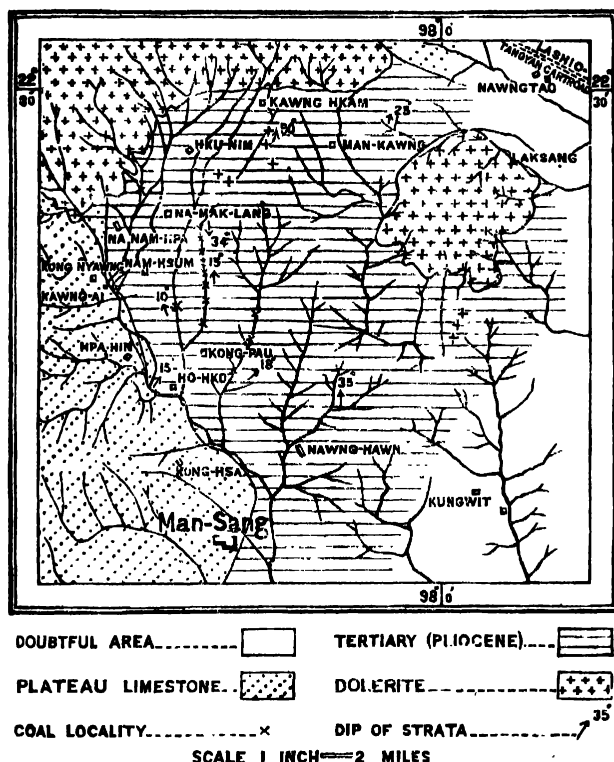


FIG. 2.—*Map of the Man-sang Coal-field.*

Commencing on the south, coal is first seen on the left bank of a stream at a point about 500 feet west of Ho-hko (22°27'; 97°57'). The section exposed in a cutting (No. 15) 8 feet long and from 5 to 11 feet deep, was:—

	Ft.	Ins.
Shale	—	
Coal		3½
Coaly shale		1½
Coal	1	5½
Shale		0½
Coal		3
Shaly coal and shale	1	3
Coal	1	0
	4	5

The dip is to N. 25° E. at 15°. Within 150 feet to north-west boundary-rock (limestone) outcrops.

In a stream five-eighths of a mile east of Ho-hko a seam of coal 10 inches thick was found. At a point 200 feet further up the same stream a coal seam, dipping N. 70° E. at 18°, occurs. Pit No. 16 was put down, the section being:—

	Ft.	Ins.
Soil and alluvial clay	12	3
Coal	2	0
Shale	1	4

About as far again up-stream a few inches of coal are to be seen. Some 2,000 feet beyond Pit No. 16 a seam of coal outcrops in two places about 100 feet apart. As first seen it is about 20 inches thick and dips N. 20° E. at 6°. At the second exposure the dip is to east at 20°, and the seam is 2 feet thick. Pit No. 17, which was sunk here, showed the following rocks:—

	Ft.	Ins.
Soil		6
Shale		6
Coal		10
Shale	1	3
Coal		2
Shale	5	0
Coal		3
Shales, coaly at base	1	5
Coal		3
Shaly coal		7
Coal . . . . exceeding		6
	11	3

Influx of water prevented further sinking, but there is probably not much more coal below. In the pit the dip of the beds is to S. 65° E. at an angle of 20°.

At a point about quarter of a mile still further up-stream coal outcrops at two points about 200 feet apart. Pits were sunk at both places, and the following sections obtained:—

Pit No. 18.

	Ft.	Ins.
Soil and clay . .	5	6
Shale . . .	1	6
Coaly shale . .		5
Coal . . .		7
Shale . . .	1	0
Coal . . .	3	5
Shale . . .		9
Coal . . .		3
Shale . . .	1	0
	14	5

Dip—0°.

Pit No. 19.

	Ft.	Ins.
Soil and clay . .	6	0
Coaly shale . .	1	0
Coal . . .	2	0
Shale . . .		1
Coal . . .	1	6
Shale . . .		6
	11	1

Dip—S. 50° E. at 15°.

On the path between Nanio and Namhsum (22°28′—97°57′) coal is exposed in a stream at a point 200 yards north-west of the first-named village. Pit No. 1 was sunk here, the section being:—

	Ft.	Ins.
Alluvial clay	3	6
Coal (partly denuded)	3	2
Shale	1	6

Dip—N. 35° W. at 10°.

In a stream at a point 300 yards south-east of Nanio an outcrop of coal, 10 inches thick, was found. On the same stream between points due east of Nanio and Namaklang, a distance of about one mile, numerous outcrops of coal occur. Over this ground twelve pits were put down, the measured sections revealed, being as follows:—

Pit No. 2.

	Ft.	Ins.
Soil and alluvium .	9	3
In the stream close to this point a seam of coal, 2 feet thick, outcrops.		

Dip—S. 50° W. at 22°.

Pit No. 3.

200 feet N. of Pit No. 2.

	Ft.	Ins.
Soil and alluvium .	2	6
Shales . . .	4	6
Coal . . .	1	0
Shales . . .	—	

Dip—0°.

Pit No. 4.

200 yards N. of Pit No. 3.

	Ft.	Ins.
Soil and alluvium	6	3
Coal	2	9
Shale	—	

Dip—NW. at 12°.

Pit No. 5.

300 feet N. of Pit No. 4.

	Ft.	Ins.
Alluvium	9	7

A thin seam of coal outcrops in the bed of the stream near by.

Pit No. 6.

100 feet N. of pit No. 5.

	Ft.	Ins.
Alluvium	4	0
Dark-coloured shales	2	6
Coal	3	0
Shale		2
Coal		3
Shale	—	

Dip—N. at 18°.

Pit No. 7.

200 feet N. of pit No. 6.

	Ft.	Ins.
Alluvium	5	0
Shales	4	0
Coal	2	3
Shale		6
Coal	1	0
Shale exceeds		9

Dip—N. at 10°.

Pit No. 8.

150 feet N. of pit No. 7.

	Ft.	Ins.
Soil	4	6
Shale	4	6
Coal	2	2
Shale		8
Coal	1	10

Dip—0°.

Pit No. 9.

300 feet N. of pit No. 8.

	Ft.	Ins.
Soil	1	6
Shale	5	0
Coal	2	0½
Shale	1	6

Pit No. 10.

250 feet N. of pit No. 9.

	Ft.	Ins.
Alluvium	2	6
Coal	1	0
Shale	1	5
Coaly shale		5
Shale	3	

Dip—N. 62° W. at 35°.

Pit No. 11.

About 2,000 feet N. of pit No. 10.

	Ft.	Ins.
Alluvium with much coal	15	0
Close to the pit a seam of coal with shale bands, about 4′ 6″ thick, outcrops		

Dip—S. 30° W. at 35°.

Pit No. 12.

200 feet N. of pit No. 11.

	Ft.	Ins.
Soil	1	0
Shale	3	6
Coal		8
Coaly shale and shale	1	6
Shale	3	6

Pit No. 13.

60 feet N. of pit No. 12.

	Ft.	Ins.
Alluvium	4	0
Shale	4	0
Shaly coal	2	7
Shale	1	5

Dip—S. 10° E. at 34°.

For nearly a mile to the north of pit No. 13 intrusions of dolerite are prominent. About a quarter of a mile south-east of Kawng-hkam (22°30′—97°58′) coal outcrops in the stream at two points 150 feet apart. At the first place the seam is 13 inches thick and dips N. 10° W. at 34°. Near the other outcrop pit No. 14 was put down and the following section exposed:—

	Ft.	Ins.
Soil and shales	3	0
Coal and coaly shale		9
Shale		5
Coal	1	8
Shale	3	0

The dip is to N. 20° E. at 50°. Within 30 feet of this point a mass of dolerite, 20 feet square, is exposed.

Near the western boundary of the field, at a point half a mile N.N.E. of Nanamhpa, coal is exposed in the bank of the stream flowing from Penghtawn. At the outcrop the seam is 20 inches in thickness. Coal outcrops a few inches in thickness are to be seen at two points about 500 feet further up the same stream.

Quality of the coal.

The coal from this locality is a hard, somewhat shaly lignite with a specific gravity of 1·40. It varies from brown to black in colour, and, although occasionally bright and lustrous, is usually dull in appearance. In general character

the coal resembles that from the Lashio and Namma coal-fields, and has the same undesirable quality of disintegeration after exposure to air and sunlight. Its chemical composition is also similar, as can be seen from the table of analyses given below :—

Table of Analyses.

No.	Locality.	Depth to top of section in feet.	Section.			Moisture.	Volatile matter exclusive of moisture and sulphur.	Fixed Carbon.	Ash.	Sulphur.	REMARKS.
		Ft. In.		Ft.	Ins.						
1	No. 4 pit	6 3	*Coal*	2	9	14·79	34·71	33·17	7·33		
2	No. 1 pit	3 6	*Coal*	3	2	16·09	36·11	33·14	9·76	1·90	Sp. Gr. 1·40.
		Ft. In.									
	No. 15 pit	5	Coal		3½						
			Coaly shale		1½						
			Coal	1	5½						
3			*Shale*		0½	14·66	34·26	39·63	11·45		
			Coal		3						
			Shaly coal and shale .	1	3						
4			*Coal*	1	0	13·50	30·64	32·49	23·37		
	No. 18 pit	7	Coaly shale		5						
			Coal		7						
			White clay	1	0						
5			*Coal*	3	5	13·04	33·35	34·58	19·03		
			White clay		9						
			Coal		3						
6	No. 8 pit	9	*Coal*	2	2						
			Shale		8	13·31	36·78	34·95	14·96		In taking the sample the shale band was thrown aside.
			Coal	1	10						

So far as the recent explorations of the Mansang coal-field have gone, no coal-seam of a thickness greater than 4½ feet has been found. The continuity of the seams is uncertain, the dip very variable, and the area much broken up by intrusions of dolerite. At the present time some fifty miles of difficult country lie between it and the railway. Even should this disadvantage not exist it is unlikely that the coal-field will ever be of much, if any, economic value.

Economic features.

III.—THE MAN-SE-LE COAL-FIELD.

Introduction.

This small patch of coal-bearing rocks has hitherto escaped notice. It lies between 22° 37′—22° 42′ and 98° 13′—98° 18′, and is situated 27 miles to E.S.E. of the Namma coal-field. It is an irregular oval in shape, the northern or longer axis being 4½ miles in length, whilst the shorter axis is about a mile less. The total area is 13½ square miles. Its average elevation is 3,100 feet, and it occupies the southern portion of an extensive amphitheatre,—elongated in a north—south direction,—composed of grassy downs, the bareness of which is but occasionally relieved by the scanty clumps of trees growing in the vicinity of the villages It is hemmed in by hills, which, on the west, attain a height of nearly 8,800 feet. The principal streams are the Nam-Tawng and the Nam-Hon, which flow across the coal-field from west to east, joining the Nam-Pawng river about a mile beyond the boundary. The Lashio-Tangyan cart-road passes within six miles of the southern boundary. The only villages of importance are Man-Se-Le (22° 40′—98° 16′) and Kunglom (called Nam-hwin) (22° 39′—98° 16′).

Geology.

There is no doubt that the rocks of this coal-field are of the same age as those of the other known coal-fields of the Northern Shan States. The only fossils found are gastropods of a species identical with those found in the Namma coal-field. The boundary of the field, on all sides, is of Palæozoic limestone. Within the area are found yellow-brown shales with occasionally a sandy character, and coal-seams. These rocks vary in dip from north-east to south-east at an average angle of 22°, the highest angle of dip recorded being 40°. Here, as elsewhere, exposures are few and far between, the rocks being covered by the usual layer of alluvial clay.

Coal outcrops and excavations.

As I was only able to spend some five or six days on the ground, the information under this heading is less complete than might be wished.

Beginning on the north, coaly shales and sandstones outcrop in the Nam-Tawng at point ⅛ mile east of Weng-Hong (22° 41′—98° 15′). They dip to N. 55° E. at 17°, and contain a coal-seam eight inches in thickness. It is here that the fossiliferous band, referred to above occurs.

In a stream at a point about a mile north of Man-se-le, traces of coal are to be found, but no outcrop can be seen until within about 3,000 feet of the village. As exposed, the coal appears shaly and is not more than a few inches in thickness.

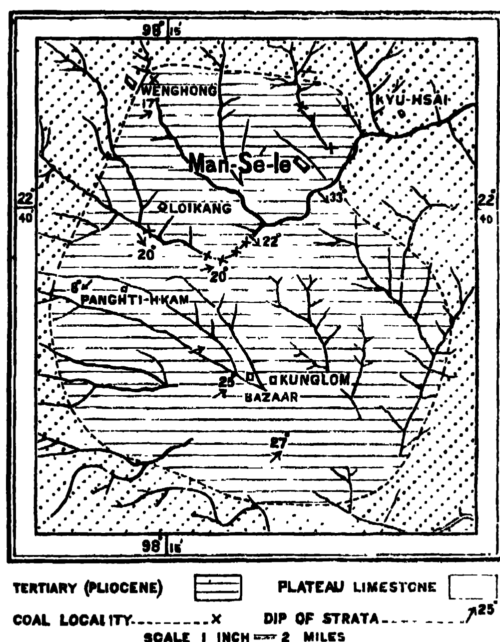


FIG. 3.—*Map of the Man-se-le Coal-field.*

At the stream-crossing on the path between Man-se-le and Kyuh-sai (22° 41′—98° 17′), and about ⅛ mile north-east of the first-named

village, a coal outcrop measuring 9 inches in thickness was found. Pit No. 1 was put down at this point, the section being:—

		Ft.	Ins.
Surface clay	. . . .	3	0
Hard coal	. . . .	1	4
Carbonaceous clay	. . . .	1	3
Bands of coal and clay	. . . .	1	5
Hard coal (with gastropods)	. . exceeding	2	6

The dip of the beds is to east at an angle of 40°.

In a stream joining the Nam-Tawng on the left bank, and at a point one mile south-west of Man-se-le, not less than 12 inches of coal outcrops. The dip of the rocks is to south-east at 22°. The following section was exposed in No. 2 pit, which was sunk here:—

		Ft.	Ins.
Surface clay	. . . .	6	0
Hard coal (sample analysed)	. . . . . .	3	2
Shale	. . . .	?	

About 100 yards further up-stream coal is again exposed, dipping south-east at 23°. This outcrop can be traced up into the flanks of the hill which the stream skirts at this point. A cutting on the hill-slope showed the rocks to be:—

		Ft	Ins.
Surface clay	. . . .	6	0
Coal with two bands of white clay, each 1½" thick	. .	4	0
Grey shales with coaly streaks	. exceeding	3	0

As the top of the seam is denuded, the full thickness of the coal is not shown in this section.

About 250 yards further up-stream, and close to the Kunglom-Weng-Hong pathway coal again outcrops. No. 4 pit was situated here, its section being:—

		Ft.	Ins.
Surface clay	. . . .	6	6
Recent pebble conglomerate	. . . . . .	2	6
Hard coal	. . . . exceeds	1	3

The dip of the seam was undeterminable. Here, as elsewhere, a heavy influx of water rendered progress slow, and, on the partial collapse of the walls the excavation was abandoned.

Some fifty yards further on about a foot of coal outcrops. Pit No. 5, after passing through some eight feet of shales with thin coaly bands, was abandoned before it reached the coal-seam. The dip is east at 20°. Less than a quarter of a mile to the west, in the same

stream, and at a point close to the path to Panghti-hkam two outcrops of coal occur. Pits Nos. 6 and 7 were put down at a distance of about 200 feet apart. The rocks exposed were :—

No. 6.

	Ft.	Ins.
Surface clay and conglomerate	7	0
Hard coal with two 1½" clay bands	3	0
Shale and coal bands	1	3

No. 7.

	Ft.	Ins.
Surface clay	3	0
Denuded coal-seam	1	6
Brown clay		3
Coal	1	5
Shale with coaly bands		10
Grey shale	1	0

The dip is to south-east at 21°. Some 300 feet further north, coal is again to be seen outcropping in the bed of the stream. The thickness is indefinite.

On the same stream, and at a point 50 feet east of the foot-bridge on the path from Loi-kang to Panghti-hkam a coal outcrop was discovered. A cutting proved a thickness of ten inches of coal dipping N. at 8°. Within a few yards the dip is 10° in the opposite direction.

Although careful search was made in the beds of all the principal streams which traverse the coal-field, yet no further outcrops of coal were encountered.

Quality and quantity of fuel.

Although it is by no means certain, yet it is probable that there are not more than one or two coal-seams of importance in the field. Pits Nos. 1 to 7 are all approximately on the same line of strike, and are probably on one and the same seam. The greatest thickness of coal met with was four feet but even in this case, the top of the seam is denuded. Without further prospecting work, however, it would be unwise to hazard an opinion as to the quantity of workable coal.

The appearance of the coal is somewhat shaly, but the following analysis of a sample from No. 2 pit shows it to be about equal in

quality with that from the other fields, although inferior to the best Namma coal :—

Moisture	14·73 per cent.
Volatile matter	38·83 ,,
Fixed Carbon	34·22 ,,
Ash	12·22 ,,

Economic features.

The fact that the coal-seam is probably of small average thickness and is of inferior quality to that from the Namma area, together with the comparative inaccessibility of the locality, make it unlikely that the coal-field will be of economic importance for very many years to come.

MISCELLANEOUS NOTES.

Fossils of the Irrawaddy series from Rangoon.

WE have received from Mr. C. K. Finlay a sample of gravel passed through at 220 feet below the surface in a well-boring at Syriam. This place is on the other side of the Pegu river to Rangoon, and the boring was made one mile from the Pegu river.

The pebbles contained in the sample are small—rarely larger than a pea—and consist of well-rounded quartz or sandy shale. Scattered throughout the deposit, apparently in great abundance, are numerous fish and reptilian teeth associated with chelonian and mammalian remains and silicified wood, of which there is one small fragment in the sample sent. These include a species of *Carcharias,* which has not been exactly determined but seems to be closely allied to *Carcharias gangeticus,* also several teeth about half an inch long, without lateral cusps and exhibiting distinct traces of serration on the upper margins, which appear to belong to a member of the *Lamnidæ* but are not of a recent type. Teeth with rounded bases, much incurved and barbed are identical with some which came from an unknown horizon at Thayetmyo in Burma and have been described and figured by Dr. F. Noetling[1] under the name of *Oxyrhina pagoda.*

Besides these are Siluroid spines and a portion of the dorsal vertebra of a Siluroid fish. A fragment of a grinding tooth may probably be referred to a Myliobatid. There are several reptilian teeth perhaps belonging to a crocodile. The chelonians are represented by portions of plates belonging to the genera *Trionyx* and *Emys.* Amongst the mammalian remains are a toothless mandible of some small animal, possibly one of the *Cheiroptera,* and a portion of a dorsal vertebra of an ox. The cellular substance of the latter is completely impregnated with iron pyrites, in the same manner as the bones from the Gangetic alluvium are with a mineral substance, which Mr. L. L. Fermor has found to be a manganese oxide. The silicified wood, a piece of not more than an inch long, is unidentifiable.

In spite of the absence of any exact specific determination of these fossils, their general character leaves no doubt that they belong to the Irrawaddy or

[1] Noetling. Fauna of the miocene beds of Burma. *Pal. Ind.*, New series, I, 3, p. 372 (1901).

Fossil wood series which is of pliocene age and which Mr. W. Theobald[1] has fully described, and to our knowledge of which Dr. Noetling[2] has subsequently contributed.

It is of course conceivable that the fossils may all have been derived from a pre-existing bed of the Irrawaddy series, and the deposit in which they are now found is a later pleistocene or recent one, in a manner similar to the fossil wood, which Mr. Theobald found embedded in these later alluvial deposits at Rangoon, and cited as evidence of a former extension of the Fossil wood series as far south as Rangoon. If, however, the sample sent is a fair average one, the fossils seem more abundant than would be expected in a derived deposit, and it is more probable that the fossil wood beds are here actually *in situ* and represent an undenuded remnant of the series obscured from view by a considerable thickness of recent alluvium. As no outlier of the series is known farther south than Prome, the occurrence of it below Rangoon is of considerable interest, as giving further proof of Mr. Theobald's conclusions as to the former extension of the group.

[GUY E. PILGRIM.]

[1] Theobald. Geology of Pegu, *Mem. Geol. Sur. Ind.*, X, 247 (1873). and Beds with fossil wood in Burma, *Rec. Geol. Surv. Ind.*, II, 79 (1869).

[2] Noetling. *loc. cit.* and *Rec. Geol. Surv. Ind.*, XXVIII, 85 (1895).

G. I. C. P. O.—No. 994 D. G. Surv.—26-3-06.—700.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1906. [April.

NOTES ON THE PETROLOGY AND MANGANESE-ORE DEPOSITS OF THE SAUSAR TAHSIL, CHHINDWARA DISTRICT, CENTRAL PROVINCES. BY L. LEIGH FERMOR, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With Plates 14 to 20.)

CONTENTS.

B

I.—INTRODUCTION.

THE following notes are based on an examination of some rocks,[1] chiefly crystalline and metamorphic, associated with the manganese-ore deposits of the Chhindwára district and collected by me in December 1903. The area dealt with lies wholly within the Sausar tahsil of the above-mentioned district, and is almost entirely included within the portion of the same district described by Mr. Datta in the following paper (pages 221 to 228); it is that part of the Kanhán Valley lying between the latitudes 21° 45′ N. and 21° 30′ N. Since detailed observations were confined to but a small portion of this area, and in view of the great variety of rocks so found (see the classification on page 166), it is justifiable to suppose that within this area many rock-types still await discovery.

Regarding the map (Pl. 20) appended to this paper a little explanation is required. The small areas immediately surrounding the different manganese-ore outcrops have been mapped on the scale of one inch to the mile (that of the accompanying map) and these isolated patches have been joined up by *enlarging* from Mr. Datta's map (Pl. 21), the scale of which is 1″=4 miles. Such a process of magnifying the geological boundaries from a small to a large scale map is not to be commended and has only been resorted to where absolutely necessary. On this map will be found numbers in red corresponding to the serial numbers of the rocks described in the sequel and numbers in blue corresponding to the various manganese-ore deposits. Much of the solid geology, especially near the Kanhán river, is obscured by alluvium, except for occasional exposures. Hence, in such areas, the crystalline and metamorphic rocks are represented on the map by a continuous pink tint without any attempt to further subdivide them into their various petrological groups.

The rocks of this neighbourhood belong to three series:—

(1) Deccan Trap (Uppermost Cretaceous).

(2) Lameta (Cenomanian).

(3) Metamorphic and Crystalline Series (Archæan).

The small amount of space devoted below to the consideration of the Deccan Trap is not due to any lack of interesting features

[1] Nos. 16·925 to 17·80 of rock register. Also Mr. Datta's specimens Nos. 9·1025 to 9·1042.

amongst its rocks, but to the fact that the object of my visit was to examine the manganese-ore deposits and the rocks with which they are associated; the time at my disposal being very limited, I was unable to undertake anything but a cursory examination of the trap.

II.—THE DECCAN TRAP.

The distribution of the rocks of this formation along the sides of the valley and their horizontally-layered character are described by Mr. Datta in the next paper (page 226) and no further general remarks are needed here. To the eye, the trap, where not amygdaloidal, presents a general sameness throughout the area, and the following specimen may be taken as typical of it.

No. 1.—16·928—4845—Basalt—Ránpet—G. = 2·98.[1]

This specimen, collected from the northern slope of the range of trap hills due south of Ránpet, is an extremely fine-grained dull blackish rock, with occasional small vesicles and shows a few small phenocrysts of a yellowish mineral, probably plagioclase. M.[2]—It shows the structure of a very fine-grained basalt. The felspar is *labradorite* occurring in laths with the usual albite twinning-lamellæ, though one phenocryst shows also pericline twinning. The *augite* is very pale brown, occurring in grains between the felspar laths, so that the structure may be described as intersertal. There are also a few slightly larger augite grains occasionally showing simple twinning. *Magnetite* often showing square outlines is abundant in grains of the same average size as the augite. There is also an orange-yellow to red substance, uniform in colour, and often quite isotropic, but at other times showing spherulitic interference crosses under crossed nicols. It may be either *serpentine* derived from original olivine, or it is

[1] The first number is the serial number of the rocks described in this paper; the second is the number in the rock-register of the Geological Survey collection; and the third the number of the microscope slide. In the title to each description, the name assigned to the rock is given and this is followed by the name of the village within the limits of which the specimen was collected. "G" stands for specific gravity. For the majority of the specific gravity determinations of the rocks described in this paper I am indebted to Mr. Ram Chandran, M.A., who also carried out a few qualitative analyses of doubtful minerals.

[2] "M" means "*microscopic aspect*" or "*under the microscope.*"

possibly glass. *Apatite* is abundant in small grains and prisms especially in the felspar.

No. 2.—16·926—4843—"Green Earth"—Wagora—G.=2·50.

In places in the trap occur irregular seams and pockets of a very fine-grained compact earthy rock usually described as "green-earth". This particular specimen was taken on the neck joining Ghoda Hill to the hill to the south-south-east. It is sage-green in colour, with G.=2·50, *i.e.*, higher than the upper limit given for glauconite. M.—Under the highest power minute *quartz* grains are seen disseminated through a matrix which is pale yellow-green and colourless in patches, and is isotropic or nearly so.

No. 3.—16·927—4844—Lavender-and-green "Earth."—Wagora—G.=2·49.

This rock is similar to the above, except that it is coloured lavender with patches of green. It was found at the head of the fourth water-course crossing the road going east from Wagora, and formed part of an obscurely exposed mass of similar rock at least five feet deep: but whether it was a bed, vein or geodic infilling in the trap could not be determined. M.—It shows occasional minute *quartz* grains in a mottled and clouded greenish-brown base.

III.—THE LAMETAS.

This group consists mainly of sandstones, limestones and cherts of which the lithological characters and distribution are described by Mr. Datta, but it will be interesting to note a specially fine example of the unevenness of the surface on which the Lametas were deposited. As shown by the map, the low ground to the south of Kára Hill is occupied by Lameta rocks—limestones, sandstones and cherts—and, at the west end, this patch of Lametas is capped by a small outlier of trap. Both Kára Hill and the hills immediately to the south of these Lametas are composed of quartz-pyroxene-gneiss, this rock being finally capped by the trap on Kásigondri Hill, where no intervening stratum of Lameta rocks was found. The evidence indicates that in this neighbourhood, before the deposition of the Lametas, the surface of the metamorphic rocks was very

similar to that of the present day, and had been eroded into hills which rose in places to at least 285 feet[1] above the valleys. The Lametas were then deposited so as to fill up these valleys and cover at least the lowest hills. This sedimentation was followed by a limited amount of sub-aerial erosion which, in addition to excavating valleys and ravines in the Lametas themselves (sometimes even cutting down to the underlying gneiss), also removed any of those rocks that may have been deposited on the higher gneissic hill-tops[2]. Flows of the Deccan Trap were then erupted so as to obscure everything, and this volcanic activity was followed by post-trappean erosion which has continued to the present day. Consequently, not only do we now see the trap resting on the gneiss, sometimes with, and sometimes without, the intervention of the Lametas, but we also see hills of gneiss rising to a higher level than those particular layers of the neighbouring trap which lie directly on Lametas in the old valley bottoms of the pre-trappean landscape.

No. 4.—16·931—4846—Gritty Limestone—Utikáta.
G. = 2·631.

This was taken from the stream due south of Kára Hill. It is partly a very fine-grained pale lavender limestone, with almost conchoidal fracture, showing little streaks of crystalline calcite; and partly a mottled mauve and greenish-white gritty limestone. M.—The former portion of the rock is almost crypto-crystalline calcite traversed by veins of crystalline calcite and containing occasional grains of quartz. The gritty part of the rock, on the other hand, shows rounded and angular pieces of quartz, often exhibiting undulatory extinction, and set in a clouded calcite matrix, of which the smallest grains can just be seen with a half-inch objective; the calcite is in places, however, large enough to show twinning. There is also a patch of the crypto-crystalline rock included in this gritty portion.

[1] This is the difference of elevation, as shown by an aneroid, between the top of the Lameta outcrop and the top of the gneiss of Kásigondri Hill.

[2] Near Chándgarh in the Nimár district of the Central Provinces is an excellent and very clear example of such pre-trappean erosion. See the *General Report, Geol. Surv. Ind.*, 1902-1903, p. 21.

IV.—THE METAMORPHIC AND CRYSTALLINE SERIES.

It is with the rocks of this series that we are mainly concerned, and owing to their variety and to the fact that they form the nidus of the manganese-ore deposits their study is one of most absorbing interest.

(A)—Geological Relations.

Roughly speaking, we have in this area a system of parallel bands of rock of different lithological constitution, with a strike varying between due east and E. 35° S., though there are, of course, deviations from these limits. Moreover, owing to faulting transverse to the strike, any one band of rock is not continuous for any great distance, *i.e.*, for not more than about ½ to 2 miles. The dips are as a rule rather steep and more usually towards the south side of the strike, but fairly frequent dips in the opposite direction suggest that these rocks are really sharply folded about axes parallel to their strike, thus accounting for the outcrop of parallel ridges of rock of the same character.

Finally, thin veins and strings and broad dykes of granite and pegmatite intersect in every direction this whole series of older rocks; they usually pass from one band to another, but are not infrequently in parallel arrangement with them by intrusion along the bedding planes.

(B)—Classification.

The following is an attempt to classify the various kinds of rock met with. As very detailed field work would have been required to establish the genetic relationships of the various lithological types, this classification must be regarded as tentative.

I.—Granites and Pegmatites.	Muscovite-granite. Tourmaline-granite. Garnet-granite. Orthoclase-quartz-pegmatite. Tourmaline-quartz-pegmatite. Spessartite-pegmatite.

II.—Granulites . Garnet-granulite.
Biotite-garnet-granulite.

III.—Gneisses . Muscovite-gneiss.
Muscovite-biotite-gneiss.
Hornblende-biotite-gneiss.
Biotite-gneiss.
Ditto , very schistose.

IV.—Schists . Biotite-felspar-quartz-schist or gnessic-schist.
Biotite-schist.
Amphibole-schists and amphibolite.
Hornblende-felspar-schist.

V.—Quartzites . Muscovite-quartzite.
Garnet-bearing quartzite.

VI.—Quartz-pyroxene-gneisses. Quartz-pyroxene-gneisses, containing some or all of the minerals:—diopside, hornblende, quartz, labradorite, microcline, epidote, garnet, sphene, zircon, ilmenite and magnetite.

VII.—Calciphyres. Containing the same minerals as the rocks of Group VI, but with the addition of calcite in either small or large quantity.

VIII.—Crystalline Limestones. May be divided into three *classes*:—

1. Contains some or all of the following accessory minerals:—diopside, hornblende, tremolite, quartz epidote, essonite, sphene, magnetite and mica; and is apparently the final product of the chemical changes involved in the formation of the rocks of Group VII, from ones identical with or similar to those of Group VI.
2. Manganiferous limestones, often containing spessartite and rhodonite, and black in colour due to the deposition of manganese-oxide along the cleavage and twinning planes of the calcite.
3. Serpentinous limestones and cipollinos, usually dolomitic and apparently resulting from the chemical alteration of original white pyroxene-rock, with or without phlogopite.

IX.—Almandite-gneiss.	Passing into calciphyre.
X.—Manganese-bearing rocks and Manganese-ores.	One type classified with the crystalline limestones and one with the pegmatites; the remainder as follows:— (*a*) Spessartite-quartz-rock. (*b*) Rhodonite-quartz-rock. (*c*) Spessartite-rhodonite-quartz-rock. (*d*) Any of above without quartz. (*e*) Rhodochrosite-rhodonite-rock. (*f*) Braunite-albite-quartz-rock. (*g*) A rock composed of alkali-felspars and a manganese-pyroxene. All the above are often altered to manganese-ore (chiefly braunite, psilomelane and pyrolusite).

(C)—Origin.

Pyroxenic Gneisses, Calciphyres and Crystalline Limestones.

Various typical rocks from the above will be described in the sequel, and a few words on their origin will not be out of place. To begin with, it is permissible to express the opinion that the rocks of Groups I and II are probably all of intrusive origin, but that the grouping of III and IV is certainly artificial, since the components of these two groups are in all probability partly metamorphosed sedimentary and partly metamorphosed igneous rocks,[1] while those of Group V may be unhesitatingly accepted as metamorphosed sediments. Groups VI, VII, VIII, and IX are most intimately connected and together furnish quite a body of evidence favouring the supposition, now put forward, that the crystalline limestones of this area[2] —at least partly—are not simply metamorphosed sediments, but result from the chemical alteration of pre-existing rocks containing an abundance of lime (and magnesia) silicates. This change necessarily involves the introduction from without of carbon dioxide, presumably in solution.

[1] See rock No. 23, page 185.

[2] Like those of Burma, as described by Prof. Judd, *Phil. Trans. Roy. Soc. London*, Vol. 187A, 205, (1896).

The similarity of the mineral constituents of the quartz-pyroxene-gneisses to those of the calciphyres, whice only differ from the pyroxenic gneisses by containing calcite in small or large quantity, points to a similar origin. Seeing that it is possible to collect specimens of calciphyres containing increasing quantities of calcite until the rock may best be described as a crystalline limestone (of class I), then it becomes quite reasonable to suppose that the crystalline limestone also originated in the same way as the quartz-pyroxene-gneiss. I do not mean to imply that because various outcrops of rock can be found showing every gradation in mineral composition between a quartz-pyroxene-gneiss and a crystalline limestone, that therefore the limestone has been derived from the gneiss by chemical alteration; the points I would emphasize are (1) that if the gneiss be of igneous origin, the limestone must also be of igneous origin, (2) that the present condition of the latter is not the same as when it was first formed, and (3) that it may or may not have originally had identically the same composition as the gneiss. Lacroix[1] has described some elliptical masses up to a foot in diameter which occur in the crystalline limestones at Cornigal (Kurnegalle), about 50 miles north-east of Colombo. One was composed of calcite, oligoclase, green pyroxene, pyrite, quartz and sphene, and another of calcite, hornblende, wernerite, oligoclase, zoisite, sphene and pyrite; and with regard to these masses Lacroix[2] remarks that "they are of great theoretical interest, for being evidently derived from the cipolins in which they occur, they present a composition comparable to that of the pyroxenic gneisses of the same region, and, in a certain measure, allow us to assume, for the latter, a similar origin." I would suggest that, on the analogy of the Chhindwára pyroxenic gneisses and crystalline limestones, the reverse may be the true explanation, and that these elliptical masses may be the partly altered remains of massive pyroxene-gneisses which have been largely converted into crystalline limestones or cipollinos. Professor Judd has assigned to the Burmese crystalline limestones a somewhat similar origin to that suggested here for those of the Chhindwára district, the chief difference being that scapolite,[3] which is not common in Chhindwára, is, according to Judd,

[1] *Bulletin de la Société Française de Minéralogie*, XII, 343, (1889). Translated by Mallet in *Rec. Geol. Surv. Ind.*, XXIV, 195, (1891).

[2] *Ibid*, 344 and 196, respectively.

[3] *Infra*, p. 194.

characteristically involved in the formation of the Burmese crystalline limestones. Judd says "that the source of the corundum and spinel and of the calcite in which these minerals are embedded, appears to be the basic lime-felspar (anorthite) and associated minerals of the pyroxene-gneisses. The anorthite is often converted into scapolite, from which calcite and various hydrated aluminous silicates have been formed by further alteration." [1]

Calcite and Dolomite.

Staining by Lemberg's solution [2] (logwood or hæmatoxylin and aluminium chloride) has shown that dolomite is not present, at least to any appreciable extent, in the crystalline limestones of class I, and in the calciphyres and quartz-pyroxene-gneisses with which they are genetically connected. The same remark applies to class II, but, as is noticed below, the serpentinous rocks forming class III are usually characterized by the presence of dolomite as well as calcite; this being of course due to the fact that the diopside and phlogopite composing the original rock are magnesian silicates, and that the former, which is usually the mineral to suffer change, also contains lime. On the other hand, the pyroxene in the quartz-pyroxene-gneisses is normally altered to hornblende in the calciphyres, and consequently the carbonate produced, being derived solely from the plagioclase felspars, which are lime silicates, is calcite with no dolomite. As, however, even this paramorphic hornblende is often quite absent in the final product of this series of changes, namely, the crystalline limestones, the magnesia must eventually have been removed in solution.

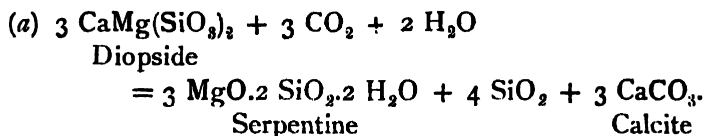
Serpentinous Crystalline Limestones and Cipollinos.

On examining the serpentinous limestones and cipollinos, which are characterized by the almost invariable presence of dolomite as well as of calcite, I found, in several specimens, undoubted cases of derivation from a rock which originally contained no carbonates at all. This is admirably shown by a specimen from Gowári Warhona (No. 38, *infra*) containing a residual patch of almost unaltered white pyroxene of which presumably the rock was originally composed. The pyroxene is surrounded by yellowish serpentinous limestone which is apparently corroding it—a process which can be well followed under the microscope (see page 202). Hence, in one hand-

[1] Judd, *loc. cit.*, 225.

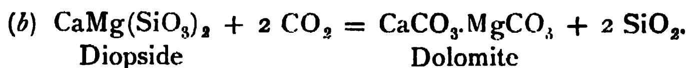
[2] *Zeitschrift der deutschen geologischen Gesellschaft*, XL, 357, (1888). Also E. W. Skeats, *Bull. Mus. Comp. Zoöl.*, XLII, 67, 1903).

specimen, and even in one microscope section, can be seen both partly and completely altered pyroxene, the final product being a rock composed of calcite and dolomite with nests of serpentine and a few bundles of tremolite (Pl. 17, fig. 2). In rocks from several other localities the same change can be seen microscopically. These rocks often contain, in addition, phlogopite-mica. The fresh rock was, therefore, either a pyroxene-rock or a phlogopite-pyroxene-rock, according as phlogopite was absent or present. In the process of alteration the phlogopite was but little changed. The change affecting the pyroxene (assuming it to have the composition of diopside)[1] may be represented thus:—



(*a*) $3\ CaMg(SiO_3)_2 + 3\ CO_2 + 2\ H_2O$
Diopside
$= 3\ MgO.2\ SiO_2.2\ H_2O + 4\ SiO_2 + 3\ CaCO_3.$
Serpentine Calcite

When, as is usually the case, dolomite also is present, then the following equation probably holds as well:—



(*b*) $CaMg(SiO_3)_2 + 2\ CO_2 = CaCO_3.MgCO_3 + 2\ SiO_2.$
Diopside Dolomite

Hence these crystalline limestones may have been produced by the percolation of an aqueous solution containing carbon dioxide (CO_2), this same solution having carried away the free silica. Assuming the following mean specific gravities for the minerals concerned, *viz.*, diopside = 3·3; calcite = 2·72; dolomite = 2·85; serpentine = 2·6; then, according to equation (*a*), 196 volumes diopside yield 106 volumes serpentine and 110 volumes calcite with an *increase* of volume of just over 10%; while, according to equation (*b*), 196 volumes diopside yield 194 volumes dolomite corresponding to a *decrease* in volume of a little more than 1%. Since, judging from microscope sections, the dolomite is never present in a greater proportion to the calcite than 1 to 1, it is evident that the formation of this rock must always have been accompanied by an increase of volume, *i.e.*, that these chemical changes took place under conditions permitting expansion.

[1] Qualitative tests show the mineral to be essentially a lime-magnesia silicate, which effervesces slightly with acid, this partial alteration to carbonates accounting for the low G.-2·99.

Almandite-gneiss.

There is at Bichua a band of crystalline limestone containing as the most important accessory constituent large rhomb-dodecahedra of essonite, besides abundant epidote, pyroxene, red felspar and other accessories (No. 35, *infra*). As a parallel band immediately to the north of this is a rock (No. 43, *infra*) composed mainly of almandite-garnet, epidote and red felspar. Under the microscope this felspar is seen to be so clouded that it is usually impossible to identify it specifically; moreover, it has often suffered a partial change into a micrographic intergrowth of calcite and quartz; and many cases can be seen of cores of clouded felspar surrounded by this micro-pegmatite (Plate 19, fig. 2). The original felspar was at least as basic as andesine and was possibly labradorite. The change affecting the anorthite portion of the felspar can be expressed by the following equation :—



$$\underset{\text{Anorthite}}{CaAl_2Si_2O_8} + CO_2 = \underset{\text{Calcite}}{CaCO_3} + \underset{\text{Quartz}}{2\,SiO_2} + Al_2O_3.$$

To account for this change we can suppose the rock to have been permeated with waters containing carbon dioxide, CO_2, together with some constituent capable of removing alumina in solution. A plausible explanation is that these waters contained an alkaline carbonate, such as that of sodium, which gave its CO_2 to the lime of the felspar and removed the alumina as an alkaline aluminate. The albite portion of the felspar may also have contributed its quota to the quartz of the micro-pegmatite, its other constituents having been carried away by these same waters.

Manganese-bearing rocks and Manganese-ores.

Turning now to the manganese-bearing rocks (Group X), it must be said that the types (*a*) to (*e*) occur in lenticles and lenticularly drawn-out bands of any thickness up to 50 feet or over (as at Kachi Dhána), while as regards length one band (at Wagora) has been traced at intervals for a mile [1]. These bands have the same strike and dip as the gneisses and schists between which they are intercalated. I do not propose to consider here the origin of these manganese-bearing rocks, while as regards the origin of the ores it will be sufficient to say that they probably result—in part at least—from

[1] In other districts of the Central Provinces much larger dimensions have been measured for the bodies of manganese-bearing rock—*vide Rec. Geol. Surv. Ind.*, XXXII, 58, (1905).

the chemical alteration of the various manganese-silicates, and that evidence obtained by me elsewhere shows that this change is one of great antiquity and is not—at least to any appreciable extent—going on now.

Further remarks on the origin of various rocks of this series will be found on pages 179 and 200.

(D)—Silicification.

Silicification of rocks has taken place on such an extensive scale in this area that it merits a separate section to itself. The following examples may be enumerated :—

(1) Formation of quartz geodes in the Deccan Trap.
(2) Silicification of Lameta limestones.
(3) Ditto crystalline limestones.
(4) Ditto gneiss.
(5) Ditto pegmatite.
(6) Ditto spessartite-quartz rock.
(7) Formation of quartz geodes in the chert derived from the crystalline limestones.
(8) Formation of chalcedony and opal in fissures and cavities in manganese-ore.

A difficulty in mapping.

It would be well to explain here how this phenomenon of replacement of diverse rocks by silica gives rise to a great difficulty in mapping. The Lametas, as is well known, form a thin layer underlying the trap and resting upon the metamorphics and crystallines. To estimate the thickness of the Lametas with any accuracy is of course very difficult owing to the way in which the débris of the overlying trap obscures the outcrops; and this same difficulty appears in many other parts of the Central Provinces and in Central India. In this area, not only have the Lameta limestones been largely converted into chert, as is seen so often wherever these rocks are found, but this silicification has penetrated to the underlying crystalline rocks so as to form remarkable pseudomorphs in chert and chalcedony after gneiss, pegmatite and crystalline limestone. Hence, even when the outcrops are well exposed and not too much obscured by trap boulders, it is often a matter of great difficulty to decide whether to map a particular exposure as Lameta or as gneiss. Moreover, the chert formed by the replacement of the crystalline limestones is so exactly like that formed by the replacement of the Lameta limestone that it is sometimes absolutely

impossible to tell where the crystalline limestones end and the overlying Lametas begin. The hill shown on the map just north of the "u" of "Doodala Kulan" is composed of serpentinous crystalline limestone capped by chert, the once-overlying trap having been entirely removed by denudation. If this cap were large enough to be shown on the map it would be justifiable either to represent it as the last remnants of the once-overlying Lametas, or simply as silicified crystalline limestone.

Silicified Pyroxene.

This widespread silicification has evidently often been a case of replacement approximately molecule by molecule, for the structures possessed by minerals and rocks prior to silicification are sometimes beautifully preserved in silica. As the best example of this must be noticed a specimen (17·68—4951 to 4953) from Gowári Warhona, in which a mass of white pyroxene has been pseudomorphed to silica, the pseudomorph showing an exquisitely banded structure representing the basal parting so well seen in the unsilicified portions of the pyroxene. In the pseudomorph these planes are delineated by thin lines of a yellowish clouded material (Plate 14, fig. 1).

Silicified Pegmatite.

Another noteworthy example (17·74—4959) was collected in Alesur village limits on the east slopes of Burár Hill about 2¼ miles a little N. of E. from Rámakona. This specimen shows large porphyritic pink felspar crystals set in a chalcedonic matrix which has replaced most of the remainder of the rock (originally a pegmatite), while in parts of the specimen the felspar also has been replaced. In this case the original structures have been largely obliterated, but former books of mica are marked out by patches of white chalcedony showing signs of banded structure, these patches being set in a black cherty matrix (Plate 14, fig. 2).

Source of the Silica.

Regarding the source and time of this silicification, the Lametas and the underlying surface of the metamorphics must have been silicified at the *same* time, and by silica derived from the *same* source. This silica was probably introduced in solution from the overlying trap, in which case the silicification of the Lametas and metamorphics must have been due to the same cause as the infilling of the geodes in the trap. The probable explanation of this latter phenomenon is that the trap when erupted was saturated with water containing in solution mineral salts and an excess of silica. Most of the mineral salts must then have been deposited as

zeolites in the steam-holes in the trap together with a certain proportion of the surplus silica, of which the remainder was carried in solution to the subjacent rocks, which it replaced more or less completely. But it must not be forgotten that there may be another source for this silica, inasmuch as the formation of the serpentinous limestones involves the release of silica in solution (see p. 171); but this does not seem so probable an explanation as the trappean origin for the silica outlined above.[1]

(E)—Detailed Descriptions of Selected Types from the Metamorphic and Crystalline Series.

I now propose to describe in more or less petrological detail, according to their interest and importance, some selected specimens illustrating most of the types as classified on pages 166 to 168.[2] The object of such work is to put on record descriptions of typical rocks which will serve as standards for comparison with the rocks of other portions of the Central Provinces (and of other parts of India). For it is only in this way that there can be any hope of unravelling the structure of the metamorphic and crystalline complex covering such a large portion of this part of India.

Group I.—Granites and Pegmatites.

No large bosses or areas of the rocks of this group have been found, their outcrops being usually quite insignificant. The granites are not what would be called typical granites, as they tend to show either pegmatitic or granulitic characters. Their exposures are always of small extent, usually—as far as can be guessed from scattered outcrops—irregular in shape and arranged without any reference to the strike of the older rocks into which they have been intruded. Much more abundant than the granites are the pegmatites, broad dykes and thin

[1] The fact that the conversion of manganese-silicates such as spessartite and rhodonite into ores of manganese such as braunite and psilomelane involves a removal of silica might also have been invoked as another possible source of the silica; but such an explanation is put out of court by evidence I have recently obtained in the field as to the extreme antiquity (Archæan) of the chemical changes accompanying the formation of the manganese-ores.

[2] In a few cases a type mentioned is not here described, because, though noticed in the field, no specimen was collected.

strings of which traverse the older rocks in every direction (see p. 166). Often showing graphic structures, the pegmatites are still more commonly porphyritic, the felspar being frequently pink, so that the water-smoothed outcrops seen in streams have a curious 'pork-pie' appearance. Muscovite is a frequent constituent of these pegmatites and has been found up to 3 inches across the cleavage planes, but it is never of economic value. One of the best places for studying the pegmatites is in the low hills 1 to 1½ miles east of Rámakona and just to the west of Burár hill. Here the prevailing rocks are muscovite and biotite-gneisses, often very schistose, and abundantly traversed by muscovite-pegmatites.

Rose-quartz.

This will be the best place to mention the occurrence, at two separate localities, of rose-quartz. At one of these it occurs as a vein (J. 694) crossing the Khairi nála about ¾ mile north-west of the village of the same name. This vein has a north-east strike, and crops out for about 150 yards; it is about 25 feet wide and of translucent to milk-white quartz in many places with beautiful shades of pink—often deep rose. The other occurrence (J. 693) takes the form of some loose blocks of amethystine-pink quartz, containing a little muscovite, on the east slopes of Dudhára Hill; the actual outcrop is obscured by débris derived from the trap-capping of the hill.

No. 5.—17·49—4936—Muscovite-granite—Dudhára.—
G. = 2·67.

This rock, which was collected from the south-west spur of Dudhára Hill, is a rather coarse-grained granite, composed of colourless quartz, decomposed flesh-pink felspar and very abundant pale greenish muscovite. M.—It shows interlocking strained *quartz* and extremely abundant *muscovite* laths. In addition, these two minerals often interlock to form composite patches, with alteration products penetrating into the quartz. The quartz is full of irregular inclusions which, however, seldom show bubbles. The *felspar* is too decomposed to appear in the section.

No. 6.—17·50—4937—Tourmaline-granite—Bichua.—
G. = 2·62.

This rock, which is situated at the very west end of the manganiferous band of Bichua, seems to cut off the ore-deposit in that direction,

It is a medium- to coarse-grained granite showing translucent quartz, pinkish felspar, and black tourmaline spots. In places it is granulitic and rather fine-grained. M.—The felspar is clouded and probably all *microcline*; the *quartz*, which is present in abundant rounded granules, is strained and often corrodes the felspar; while the *tourmaline* is of a peculiar purplish-brown colour, shows total absorption, and tends to be pegmatitically intergrown with the felspar. The whole structure of the rock resembles that of a granulite.

No. 7.—17·58—4944—Graphic-granite (pegmatite)—Alesur.—G.=2·59.

This was collected on the south-east hillock of the three shown south-south-west of the name on the 1-inch map. The whole specimen is part of one crystal of pink felspar intergrown throughout with quartz which imparts a graphic appearance. It shows *c* and *b* cleavages and a rough fracture parallel to *a*. The *b* face shows perthitic striation roughly parallel to the vertical axis, while on *c* these perthite laminæ are seen to be not quite parallel to the axis $\bar{b}$. M.—The rock consists of an intergrowth on a large scale of *microcline* and *quartz*, each mineral being represented by only one individual. The irregular, numerous and roughly parallel *perthite* bands are seen to have a mean course deviating 10°—20° from the $\bar{b}$ axis. The perthite is itself twinned and is *albite*, showing under crossed nicols a slightly higher interference colour than the microcline. (Plate 15, fig. 1.)

No. 8.—17·57—4943.—Graphic-granite (pegmatite) with striations—Kachi Dhána—G.=2·58.

This rock was collected near the head of the streamlet running past the north side of the village. It is composed of pink felspar and pale greyish quartz, there being a tendency for the quartz to lie in roughly parallel layers in the felspar. Having placed the specimen with the crystallographic axis, $\dot{c}$, vertical, both the quartz and felspar are seen to be grooved on the surfaces of contact of the two in a horizontal direction, indicating that some movement has taken place, probably before the complete solidification of the rock. In one specimen the basal cleavage planes of the felspar often show good graphic figures in quartz which sometimes seem to outline prismatic quartz crystals with pyramidal terminations. On the basal plane of another

specimen the edges of the above-mentioned thin, parallel, quartz layers are seen traversing the felspar in a direction about parallel to the prism *m*. There is also some deep greenish-brown biotite. M.—The ***quartz*** shows undulatory extinction and is becoming granulitized. The felspar is ***microcline***, the cross-hatching of which, seen under crossed nicols, is in places excessively minute. In the microcline are irregular lenticular bands of some other felspar producing a perthitic appearance, and all extinguishing at the same time. A little secondary ***muscovite*** is also present. The rich brown ***biotite*** flakes are not elastic, presumably due to alteration, but give a uniaxial figure.

No. 9.—17·53—4940—Quartz-felspar-rock—Alesur—G. = 2·66.

This rock occurs as a band 2 inches thick intruded parallel to the strike into a crystalline limestone which crops out just west of the Ghondi Nála at a point due west of Devi. It is a pinkish rather coarse-grained rock seen, M, to consist chiefly of ***microcline*** and ***quartz*** (with undulatory extinction) together with some ***oligoclase*** and ***orthoclase***, and a little minute ***sphene*** and ***calcite***, colourless ***mica*** and ***chlorite***. The three last-named minerals are probably secondary in origin and derived from the felspars, as also is an indeterminate mineral suggesting zoisite. In places the microcline and quartz are graphically intergrown.

No. 10.—17·59—4945—Tourmaline-quartz-pegmatite—Alesur—G. = 2·83.

The specimen was found as a loose piece on the hillock to the S.S.W. of the name on the map, and shows tourmaline and ***quartz*** in about equal quantities, graphically intergrown in places. The ***tourmaline*** is often in hexagonal prismatic crystals of the usual type. One was extracted which was nearly two inches long, gradually tapered, showed signs of distortion and was longitudinally striated. The rock in one place shows a little cream-coloured ***felspar***. M.—A basal section of the ***tourmaline*** showed zoning in shades of olive-green and indigo-blue, while a longitudinal section yielded the following pleochroism scheme :—

ω = complete absorption.
ϵ = sepia-brown.

No. 11.—17·56—4942—Pegmatite with pale sea-green mica and manganese-garnet—Kachi Dhána—G.=2·63.

Cropping out near the head of the streamlet which runs to join the Paumondi Nála to the W. of N. of the village, occurs the above rock intrusive in biotite-gneisses. Besides the quartz, pink and white felspars, and the mica—which did not give a reaction for chromium—are some tiny brownish-red *garnets* of which one was seen to be a rhomb-dodecahedron. They gave a decided reaction for manganese. M.—The *quartz* and *felspar* are almost graphically intergrown, as also are the quartz and *mica.* In the latter case the appearance is that of mica corroded by the quartz subsequent to its formation. The felspar is, at least partly, oligoclase, and is often much altered.

No. 12.—17·62, 17·63—4946, 4947—Spessartite-pegmatite—Bichua.

This rock is found near the west end of the second of the Bichua ore-hillocks, counting from west to east, and is probably intruded into the ore-body, which is composed of spessartite-bearing rock and manganese-ore. The specimen is composed of *spessartite,* in separate and aggregated trapezohedra up to one and two inches in diameter, together with *quartz* and cream-coloured pearly felspar, which though sometimes free from quartz sometimes also includes it. The spessartite varies in colour from orange-red to dull brown-black and is made up of concentric layers often well seen on surfaces where the growth has been arrested by contact with quartz. One crystal gave G.=4·02. M.—The *felspar* shows no twinning and but very little cleavage, but it is much strained, giving undulatory extinction and even showing incipient granulitization, and is full of irregular or rounded quartz inclusions. Specific gravity determinations show the felspar to be intermediate between albite and oligoclase.

In one place the graphic rock of quartz and *tourmaline* (No. 10, *supra*) was found joined to this rock.

Group II.—Granulites.

No. 13.—17·44—4931—Garnet-granulite—Wagora—G.=2·64.

This rock crops out at a point in a stream-bed situated about half a mile S. E. of the village; it dips steeply to S. 30° W. and is overlain by very schistose garnet-bearing gneiss. It is a whitish

medium- to fine-grained rock, with abundant chocolate-brown garnets varying in size from that of a pin's head to nearly ¼-inch in diameter. M.—The rock is seen to consist of a medium-grained granular aggregate of microcline, quartz, orthoclase, garnet and muscovite. The *microcline* is quite fresh, while the *orthoclase* is clouded and altered with development of sericite. The *quartz* often takes the form of *quartz de corrosion* encroaching on, and occurring in, both the microcline and orthoclase. (Plate 15, fig. 2.) The *garnet* is pink with the sericite from the adjoining orthoclase invading its periphery, while the *muscovite*, usually of secondary origin as a sericitic alteration product of orthoclase and garnet, is in one case graphically intergrown with microcline.

No. 14.—17·45—4932—Biotite-garnet-granulite—Wagora—G. = 2·65.

After some quartzose schists, pegmatite and spessartite-bearing rock, and a little further down-stream than No. 13, this granulite crops out with massive bedding, showing a dip at 35° to S. 30° W.

It is similar to the above (No. 13) except that small *biotite* scales are visible in the hand-specimen, while, M, the *orthoclase* of No. 13, is here replaced by *microperthite*. Such mica as is present in the section is brown ragged biotite very much altered.

Group III.—Gneisses.

The gneisses, excluding the pyroxenic gneisses, are the principal metamorphic rocks of this area, and it is in these gneisses that the other rocks occur as parallel, often lenticular bands. They are usually ordinary muscovite- and biotite-gneisses, sometimes hard and sometimes very schistose and soft so that they easily weather away. These and the schists are perhaps the most ancient rocks of this area.

No. 15.—17·42—4930—Granulitic Hornblende-biotite-gneiss—Jarola—G. = 2·81.

This was collected from the S. E. end of the ridge shown on the map just to the south of the name of the village, and is a fine-grained white rock with greenish-black spots and mottlings up to ½ an inch

in length and composed of an intergrowth of hornblende and biotite. These spots tend to be drawn out. M.—The white base consists of a fine- to medium-grained granular aggregate of *quartz* and *microcline* corroding each other, with a very small amount of plagioclase, probably acid labradorite. Round grains of quartz also occur in the hornblende, while in the midst of a patch of iron ore (ilmenite) several round individuals of quartz and microcline are seen. The *hornblende* and biotite are intergrown, sometimes with rough parallelism and sometimes quite irregularly. The hornblende has as its pleochroism scheme :—

𝔞 = greenish yellow.
𝔟 = not seen in slide.
𝔠 = bluish- or verdigris-green.

The *biotite* shows pale straw to strong brown pleochroism and is changing largely into *epidote,* patches of which are often situated right inside it. The abundant black iron-ore is presumably *ilmenite* as it often has an irregular border of *sphene. Apatite* is also present. This rock, though placed here, probably has affinities with the quartz-pyroxene-gneisses as will be seen by a comparison of the mineral contents and specific gravity of the two rocks. The field occurrence of this rock suggests the same affinity.

No. 16.—17·39—4927—Biotite-gneiss (Gneissose-granite)—
Kachi Dhána—G. = 2·68.

Found as a loose boulder about one mile west of the village, this rock is rather coarse-grained, with streaks and patches of dark greenish-black biotite on a pink back-ground of quartz and felspar. M.—Shows granitic structure. The most abundant mineral is slightly clouded *microcline.* There are also present :—a much kaolinized felspar (? *orthoclase*) ; strongly absorbent *biotite* with very ragged edges, usually straw and brown in colour, but sometimes green ; not very abundant strained *quartz* sometimes occurring as little patches in the microcline ; *zircon,* occurring as a few rather large crystals, one of which shows a square basal section. The order of crystallization is as follows :—zircon ; biotite ; the kaolinized felspar ; microcline and quartz about the same time. The rock is probably better called a gneissose-granite.

No. 17.—17·37—4925—Schistose Biotite-gneiss—Ránpet—G. = 2·73.

About ½ mile below Ránpet this rock crops out in the bed of the Kanhán river with a strike of E. 22° N., vertical. It shows extremely abundant small biotite scales arranged in folia with white felspar and quartz, the felspar individuals being usually rather small while the quartz is at times quite large. M.—The structure is seen to be granitic and the minerals are:—*quartz*, strained; *orthoclase*, untwinned and showing incipient kaolinization; *oligoclase*; *biotite*, in abundant corroded plates, usually of pale brownish-yellow to deep brown pleochroism, but of which some is only slightly pleochroic having perhaps undergone slight alteration; *apatite*: *zircon*, included in the biotite. The chief constituents are the quartz, orthoclase and biotite.

Group IV.—Schists.

No. 18.—17·30—4924—Biotite-felspar-quartz-schist—Dudhára.

This rock occurs on the S. E. spur of Dudhára Hill closely associated with a band of spessartite-quartz rock and dipping at 50° to the S. W. It is extremely schistose and crumbly showing quartz, decomposed white felspar and golden-brown *mica* scales (biotite). M.—With great difficulty a very poor microscope section was prepared and this showed that the *quartz* is extremely strained, and contains lines of inclusions, while the *felspar* is very clouded and not identifiable, but is probably orthoclase or microcline

No. 19.—17·29—4923—Biotite-schist—Dudhára Kalán—G. = 2·81.

On Sárha (Sarda) Hill just to the east of the village there is a band of this rock intercalated in the coarse biotite- and muscovite-gneisses, the dip being 50° to 60° to the S. 10° E. Dark greenish-black mica, up to one inch or more across the plates, is the chief constituent of this handsome rock, but the specimen also shows a band of felspar-quartz-biotite rock of medium grain. M.—Big brownish-green plates of *biotite* contain *zircon* (?) crystals, each of which is surrounded by a rich brown halo not appreciably pleochroic. In the spaces between the biotite occur abundant *microcline* and some *orthoclase* (?) with a very small amount of *quartz*. Some of the supposed zircons are also included in the felspar.

No. 20.—17·28—4922—Tremolite-actinolite-schist—Rámakona—
G.=2·93.

About one mile due east of Rámakona there is a small hillock—just to the east of the "Oopaea N." of the map—on which are scattered loose pieces of this rock, which is coarsely crystalline and composed of light greenish amphibole exhibiting the platy or bladed appearance of tremolite and actinolite. M.—The rock is seen to consist of a bladed mass of amphibole, with some interstitial *chlorite* of pale yellowish and greenish tints. The interiors of the blades are often composed of *actinolite* having an extinction angle up to 18° referred to the length of the crystals and showing the following pleochroism scheme:—

a = yellow-green.
b = green.
c = green.

Surrounding the central core of actinolite is a well-defined outer shell of colourless *tremolite* traversed by cross-fractures which do not usually extend to the actinolite. Many prismatic sections are seen in which the tremolite shell shows straight extinction at the same time that the actinolitic core has an extinction of maximum obliquity. Some prismatic sections, on the other hand, show an intergrowth of these two minerals forming one individual so that both extinguish simultaneously. These facts indicate that sometimes the two minerals form optically one individual and that at other times the outer shell of tremolite has a different optic orientation to the actinolitic core. The few cross-sections seen confirm this result. Besides the compound individuals, there are examples composed entirely of one only of these two minerals. Irregular patches of *iron-ore* (? magnetite) have developed in both amphiboles as if by replacement.

No. 21.—17·27—4921—Actinolite-schist—Gowári Warhona—
G.=2·96.

This rock crops out, in a stream-bed about ⅛ mile N. of W. of the village, as a thin band in a series of the common micaceous schists and gneisses of the area. It is grey-green in colour, schistose, and contains a few golden *mica* scales M.—Practically everything is *actinolite* in roughly parallel arrangement with just a trace of interstitial *chlorite* or *serpentine* and a very little *magnetite*.

No. 22.—17·22—4916—Hornblende-schist—Alesur—G.=3·10.

A pebble of this rock was found in the Ghondi Nála east of Burár Hill. Dark green in colour with schistose structure, it consists almost entirely of short-bladed dark-green hornblende with a little whitish interstitial matter. M.—The amphibole is common green *hornblende* with its pleochroism scheme as follows :—

$\mathfrak{a}$ = pale straw.
$\mathfrak{b}$ = rich green.
$\mathfrak{c}$ = bluish green.

Absorption scheme :— $\mathfrak{b} > \mathfrak{c} > \mathfrak{a}$. Extinction angle on clinopinacoidal sections = 15° to 18°. The grey, clouded, interstitial matter could not be determined.

No. 23—17·23—4917—Plagioclase-hornblende-schist—Bichua—G.=3·10.

On the north slope of the shoe-shaped hill forming a S. W. spur to Burár Hill, this rock crops out below the almandite-gneiss, mentioned on p. 172, with which it forms a parallel band. Schistose and of medium grain, this rock consists mainly of dark green hornblende with yellowish-green epidote patches and white flecks due to felspar.

M.—In the first section cut the two chief constituents are hornblende, with more or less of parallel arrangement, plagioclase and black iron-ore. The *hornblende* possesses the following pleochroism :—

$\mathfrak{a}$ = straw,
$\mathfrak{b}$ = green, with a brown tinge,
$\mathfrak{c}$ = rich green, with a bluish tinge in thick sections ;

and has as absorption scheme, $\mathfrak{b} > \mathfrak{c} > \mathfrak{a}$; whilst the maximum extinction-angle referred to prismatic cleavage-traces observed on clino-pinacoidal sections, *i.e.*, $\mathfrak{c} \wedge \dot{c}$, is 18°. Occasional remains of *pyroxene* and patches of epidote are seen in association with the hornblende. Another thin slice was then prepared in which the pyroxene was found to be in many parts nearly as abundant as the hornblende. The pyroxene is a pale green, practically non-pleochroic, variety with extinctions up to 40° on clino-pinacoidal sections, and, judging from the way in which it is often surrounded by and intergrown with hornblende, there is not much doubt that the latter

mineral has been formed at the expense of the pyroxene. This pyroxene occurs as individuals of very irregular shape, which often have rounded boundaries, but are evidently idiomorphic with respect to the plagioclase. The *felspar* is present as allotriomorphic individuals often much altered by the protrusion into them from their peripheries of bunches and tufts of tiny fibres and aggregations of an indeterminate mineral. These 'saussuritic' alteration products often entirely cover the space once occupied by felspar, but where clear remaining patches of the latter are visible, extinction angles up to 20° referred to the albite twinning-lamellae can be measured, thus indicating a felspar at least as basic as oligoclase-andesine. Some *quartz* is present in parts where the felspar is pretty fresh, and it then suggests *quartz de corrosion*. *Epidote* in shapeless, often granular, patches is rather abundant in that slide in which pyroxene is scarce and looks like an alteration product of the hornblende with which it is usually closely associated, though it is also seen as small patches in both the pyroxene and the felspar. *Apatite* in idiomorphic prisms and *black iron-ore* are both very plentiful. The latter substance is probably *ilmenite*, as it is frequently surrounded by a thin rim or border of *sphene*, which has no doubt been produced by a reaction between the ilmenite and the lime of the felspar; but whether this reaction took place at the time of solidification of the rock, or subsequently, as a concomitant of the other changes, cannot be determined. Some *zircon* is also present.

The evidence, then, indicates this to be a rock of igneous origin, which was originally composed of green pyroxene, plagioclase, ilmenite (and magnetite?), apatite and zircon. The pyroxene has suffered paramorphism into hornblende, while the plagioclase has become largely 'saussuritized,' and the ilmenite shows signs of change to sphene. The above rock was examined in the light of Dr. Smeeth's recent paper, "The Occurrence of Secondary Augite in the Kolar Schists,"[1] in which evidence is adduced favouring the supposition that the green augite, there found in hornblende-schists of Dhárwár age, has been secondarily produced from the hornblende (itself a paramorphic derivative of hypothetical original brown or purplish augite) under the influence of acid intrusives posterior in age to the formation of the hornblende-schists. In the absence of more

[1] *Bulletin* No. 3, *Mysore Geol. Dept.*, (1905).

numerous specimens it is impossible to settle this point as applied to the Chhindwára rocks, *i.e.*, whether the green pyroxene of this rock is a remnant of the original pyroxene which yielded by paramorphism the hornblende of the hornblende-schists, or whether it is the result of the reconversion of the hornblende (no doubt derived, under the influence of dynamic metamorphism, from *some* form of pyroxene) into pyroxene under the influence of some subsequent intrusion. What evidence there is suggests, however, the primary origin of this pyroxene, as the thin section certainly seems to show pyroxene passing by paramorphism into hornblende (though Smeeth says that his secondary augite, also, often undergoes this change). In fact this rock, together with all the amphibolites and hornblende-schists of this area, is probably of analogous origin to the hornblende-schists occurring at the edge of the Giridih coal-field and considered by Mr. Holland to be derived from augite-diorites.[1]

No. 24.—17·24—4918—Amphibolite—Ránpet—G.=3·03.

This amphibolite which is exposed in the bed of the Kanhán river opposite Ránpet, is about 12 paces wide and strikes east and west. It is a dark green rock traversed nearly at right angles by an irregular dyke of pegmatite or coarse-grained granite composed of *biotite*, quartz and felspar which is in some places pink and in others white. The amphibolite is veined and streaked in all directions by either quartz alone, pale pinkish-white felspar alone, or both together; these veins and streaks may either be free from or may contain biotite or hornblende. In one place the basic rock is so marked with little drawn-out quartz-felspar patches one to three inches long, that it looks as if the dark green rock were plastic when it was injected by the pegmatite. This latter was apparently able to send out veins in all directions, and to force into the basic rock large spherules or drops of its substance. The included patches so formed have, on their edges, often intermixed with the basic rock so as to show gradual transitions from one to the other. There is a tendency for the veins and drawn-out patches to strike W. 40° N.

The specimen collected is medium-grained, dark greenish-black and composed principally of hornblende, but has white streaks and

[1] *Rec. Geol. Surv. Ind.*, XXVIII, 123, 125, 126, (1895).

patches of felspar and quartz here and there. M.—The *hornblende* shows the following pleochroism :—

𝔞 = pale straw-yellow.
𝔟 = brownish olive.
𝔠 = green (slightly brownish).

It is often almost idiomorphic and in one case is twinned on the orthopinacoid. There is also a peculiar very pale green to colourless amphibole of apparently secondary origin with :—

𝔞 = pale yellowish.
𝔠 = pale sea-green.

The *felspar* which is considerably altered to an indeterminate aggregate probably approaches andesine in composition. There is a little *quartz* usually in small rounded grains and in some cases included in the hornblende. Besides a little *zircon*, *sphene*, and *magnetite*, there is abundance of *apatite* usually located in the felspar.

Group V.—Quartzites.

These rocks, so common in the immediately adjoining portions of the Nágpur district to the south, where they usually contain more or less muscovite, are not of very frequent occurrence in this area. Of the two types described below, 17·76 is very doubtfully placed in this group, as it might instead be a very acid microcline-gneiss.

No. 25.—17·76—4961—Microcline-quartzite—Khairi—G. = 2·61.

This specimen was collected from a huge block lying on the surface about 1 mile W. N. W. of Khairi (Khyree Tygaon). The block showed also some radiate *tourmaline*. The rock may be described as a coarse-grained vitreous pinkish quartzite containing magnetite, glassy microcline showing brilliant cleavage faces, and some muscovite. M.—The thin section shows a coarse-grained interlocking mass of *quartz* (undulatory extinction) and fairly fresh *microcline*, with a little altered *muscovite* and some *magnetite*.

No. 26.—17·78—4963—Garnet-bearing Micaceous Quartzite—
Alesur—G. = 2·63.

This was collected from the E.-W. ridge situated to the S. W. of the village-name on the map. It is a vitreous, rather cavernous,

impure quartzite of greyish colour. M.—It shows rather big plates of undulatory *quartz* with included pale pink *garnets*, which also occur at the boundaries of the quartz individuals. Though they have a distinct idiomorphic tendency, yet the garnets are often corroded by the quartz. In the latter, and often passing from one individual to another, are abundant tiny laths of *mica*, light brown in colour, with a pinkish tinge. Red *hematite* is present in thin strings, together with some scattered opaque black mineral of hexagonal cross-section.

Group VI.—Quartz-pyroxene-gneisses.

This is a very peculiar group of rocks, and, as already mentioned, (p. 169) probably has a genetic connection with the crystalline limestones. Several large outcrops of these rocks, tending to form well-marked ranges of hills, occur in this area. The rock is especially abundant in the large mass of hills to the S. E. of Utikáta, and if the capping of trap could be removed, it would probably be found to be, in that neighbourhood, the predominant rock-type. There is no mistaking the rock in the field, since it possesses a quite characteristic macroscopic appearance, for which see the description of No. 27 given below. The mode of weathering, moreover, is noteworthy, as there is a tendency for certain of the minerals, such as garnet, epidote and pyroxene, to be arranged in bands so that the more rapid weathering away of the felspathic bands in between, leaves upstanding ridges of the minerals mentioned. The prominence of this phenomenon varies greatly from one exposure to another, and even where the differential weathering is very marked freshly-trimmed hand-specimens often fail to show any marked banded structure, while, microscopically, any particular arrangement of the minerals is usually imperceptible. The specific gravity of these rocks ranges from about 2·84 to 2·93. As regards one or two of the minerals of the rock; the *felspar* ranges between andesine-labradorite and basic labradorite, corresponding to extinction angles, measured with regard to the albite lamellation, of 25° to 41°; the *pyroxene* has not been analysed but is probably diopside; the *hornblende* and *epidote* are probably always secondary; reddish brown *garnet* is a frequent but not constant constituent; *quartz* is always present, though in varying amount, while *microcline* is nearly always found: the black iron-ore, though sometimes undoubtedly *magnetite*, is probably often *ilmenite*, as it is

frequently bordered by a rim of *sphene* ; the latter mineral, therefore, which is one of the most constant constituents of the rock, is probably often, if not always, of secondary origin ; *calcite* if present is always secondary. Hence we may deduce that the original fresh rock was composed of labradorite, diopside, quartz, magnetite or ilmenite, apatite, and zircon with microcline (usually) and garnet (often); and that the calcite and uralitic hornblende are undoubtedly secondary, while the epidote and sphene have, at least in certain cases, a similar derivative origin.

No. 27.—16·939—4854—Quartz-pyroxene-gneiss—Utikáta—G. = 2·92.

This rock forms the range of hills of which the west end is marked as "Kara H." on the map ; the specimen was taken where the stream-bed shown cuts between this hill and its westward continuation. The actual outcrop had a strike of W. 20° N. with the dip obscure. The rock is rather fine-grained, somewhat granular in appearance, of a general greenish-grey colour, and is exceedingly tough and compact. The greenish-grey colour is due to dark green grains of pyroxene and yellow-green grains of epidote sprinkled in a whitish groundmass of quartz and felspar of which the grains are roughly the same size as those of the pyroxene and epidote. M.—The rock has a pan-allotriomorphic structure, in which none of the more prominent minerals are markedly idiomorphic. The minerals seen are :—*plagioclase* sometimes zoned, and then consisting of labradorite of medium composition inside with an outer shell of acid labradorite; *microcline*, fresh and small in amount; *pyroxene*, varying from pale to quite strong green in colour (a single individual being often irregular as regards the depth of the green), practically non-pleochroic, and having an extinction angle of 35°—40° measured on those sections nearest the clino-pinacoid; *hornblende*, both intergrown with the pyroxene and bordering it, and showing the following pleochroism scheme :—

𝔞 = yellow-green,
𝔟 = emerald-green,
𝔠 = blue-green ;

quartz, fairly abundant, and usually not much strained ; *epidote*, which may be secondary, as it seems to have grown around a nucleus of some other mineral such as sphene, itself possibly of secondary origin; *calcite*, just a little, no doubt secondary; *sphene*, abundant,

more or less idiomorphic (wedge-shaped), and as a rule nearly colourless, but sometimes with cinnamon-brown patches in the centre; ***zircon*** and ***iron-ore*** (? ***ilmenite***) both in fair amount.

No. 28.—16·938—4853—Quartz-pyroxene-gneiss—Sáhanwári—G. = 2·84.

This specimen was collected from the same run of rock as the previous one, the actual spot being in a ravine descending from the north side of these hills towards Khairi (Khyree Burosa), and hence about 1¼ mile east of No. 27. Both the macroscopic and microscopic aspects of this rock are very like those of the preceding, with the colour, however, somewhat lighter and the green spots a little larger. M.—The following points are, nevertheless, worth noting:—the ***plagioclase*** is slightly more basic labradorite than in No. 27; throughout the ***pyroxene*** are abundant tiny uralitic patches and besides this partially uralitized pyroxene there are also a few individuals which are entirely ***hornblende***; the abundant ***sphene*** is colourless and pale-brown in patches, and in addition to the isolated sphene individuals there is often a thin rim of sphene round the black iron-ore which is hence probably *ilmenite*. There is also an abundance of small crystals of ***apatite***.

No. 29.—16·932—4847—Quartz-pyroxene-gneiss—Kodadongri—G. = 2·84.

Collected from the hillocks about ⅝ of a mile to the E. S. E. of the village. The hand-specimen is similar to usual except for the abundant magnetite and the pinkish colour of the felspar. M.—The chief interest of this rock lies in the fact that it is evidently much more altered than either of the preceding examples, as there are now only remains of pale-green ***pyroxene*** to be seen in the ***uralitic*** pseudomorphs. The iron-ore is also largely ***magnetite*** and occurs in large irregular grains. The ***plagioclase*** is more acid than usual, being acid labradorite.

No. 30.—16·937—4852—Quartz-pyroxene-gneiss beginning to pass into a Calciphyre—Devi—G. = 2·88.

This rock was taken about one mile east of Devi from the top of a high hill composed chiefly of crystalline limestones and calciphyres,

It is a rather fine-grained rock with a very large proportion of minerals other than calcite visible in the hand-specimen; among such are small grains of epidote and dark-green pyroxene, with red-brown garnet up to ¼ inch diameter. M.—It is formed of the usual aggregate of *quartz*, *microcline*, *plagioclase*, *garnet* (light cinnamon-brown), *epidote*, *pyroxene* and *sphene*, with the addition of a fair proportion of *calcite* which seems to be replacing the microcline and is no doubt secondary. Plate 16, fig. 1, represents this rock which is quite typical of this group.

No. 30A.—9·1026—1338—Scapolitized Quartz-pyroxene-gneiss—Maleygáon—G. = 2·92.

The locality for this specimen collected by Mr. Datta is the foot of the ridge on the left bank of the Kanhán river between Maleygáon (21° 31′—78° 59½′) and Poreyghát (21° 32′—78° 58½′). It has the usual macroscopic appearance, but in one place a quartzose band contains a dark greyish mineral in prismatic individuals up to ⅜ inch long. The microscope shows this to be one of the scapolite group and, as one piece gave G. = 2·746, it is possibly *meionite*. It contains, orientated parallel to the vertical crystallographic axis, a large number of rods, some of which are very long and thin, while others are stumpy with pyramidal terminations. They seem to be opaque, but this is probably due to their very high refractive index[1]. One band in the hand-specimen contains deep purplish-red *garnet* and a section cut from this showed great abundance of *scapolite* and *calcite*, but no felspar; while a section cut from a part of the rock free from garnet showed abundance of *felspar*, microcline and labradorite, but no scapolite and very little calcite. Both slides showed *pyroxene*, *epidote*, *sphene* and *quartz*. Assuming the scapolite and calcite to be secondary minerals, their association with the garnet—which is orange-brown in section—throws out a hint that the latter may also be of secondary origin.

[1] For descriptions of similar inclusions see:—

Coomáraswámy, "The Crystalline limestones of Ceylon," *Q. J. G. S.*, LVIII, 418, (1902).

Lacroix, "Contributions à l'étude des gneiss à pyroxène et des roches á wernerite," *Bull. de la Soc. Franç. Minéral.*, XII, p. 99 and fig. 6, (1889). In a scapolite-pyroxene-gneiss from Loire-Inférieure.

Group VII.—Calciphyres.

As previously noticed (p. 169) these rocks may be regarded as linking up the quartz-pyroxene-gneisses and crystalline limestones. The term "calciphyre" of Brongniart is used here for those crystalline calcareous rocks which contain a large proportion of accessory minerals, these being the same minerals as characterize the preceding group, the quartz-pyroxene-gneisses. When the calcite is absent or but small in quantity and the so-called accessory minerals predominate, then the rock has been placed in Group VI. When the calcite is predominant and the accessory minerals are small in amount, then the rock has been relegated to the succeeding Group VIII, the crystalline limestones.

No. 31.—16·934—4849—Calciphyre—Gowári Warhona—G. = 2·82.

Found in the stream-bed to N. E. of the village, the hand-specimen may be described as a grey crystalline limestone containing green, brown and pink accessories collected in bands. M.—It is a granular mass of *calcite, quartz* and *microcline* in which are set *sphene* and masses composed of *epidote, quartz, actinolite* needles and a white cloudy material. These aggregations are probably altered pale-green pyroxene, which is often seen only partly altered or broken up by a network of fine-grained material which may be calcite. There is also another mineral which has been very doubtfully referred to *idocrase*.

No. 32.—16·936—4851—Calciphyre—Devi—G. = 2·74.

This specimen was taken from the southern of the two hillocks, situated at the western end of the village, where the rock dips to the north at a fairly high angle. It forms part of a range of hillocks and small hills of calciphyres and crystalline limestones stretching east from Devi village. The rock is a medium-grained crystalline limestone containing abundance of accessories, of which dark greenish-black striated hornblende is specially noticeable, while a little epidote and reddish-brown *garnet* are also visible. M.—*Calcite* is very abundant in rather large well-twinned plates, in which the twinning planes are often curved. *Quartz* is fairly abundant in comparatively

large grains showing undulatory extinction and is evidently being replaced by calcite in places, as fine projections of the latter branch off from the main mass of a calcite grain and penetrate the quartz. The *felspar*, as far as can be judged from the few clear portions seen, is oligoclase-andesine; but it is usually much altered, apparently into calcite, for plates of the latter send projections into the felspar. One case is seen in which felspar is surrounded by an *epidote* border. The *hornblende* is abundant and possesses the following pleochroism scheme:—

𝔞 = straw-yellow.
𝔟 = deep Hooker's green.
𝔠 = strong bluish-green.

The colours are very patchy, that corresponding to the 𝔠 axis being noticeably much lighter in places. Though no pyroxene is now visible, it is suggested that this hornblende represents it. Besides a little *sphene* there is also a zoned brown mineral which is perhaps *allanite.*

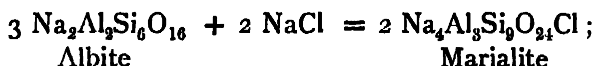
No. 32A.—9·1031—1341- -Calciphyre containing scapolite—Maindi —G. = 2·86.

This specimen was collected by Mr. Datta from about one mile S. by E. of Maindi (21°34′—78°57½′), not shown on the accompanying map, but marked on the map (Pl. 21) accompanying Mr. Datta's paper. Taken as a whole it is a medium-grained granular crystalline rock of greyish colour, showing a greyish-white background of felspar, scapolite, quartz and calcite with scattered granules of dark greenish-black pyroxene and yellow-green epidote, together with larger patches of deep brownish-red garnet. M.—It is seen to be a somewhat granular rock composed of a variety of minerals. The *garnet* is large, orange-brown, and usually bordered by, or enclosed in, *epidote*, which is also associated with the *pyroxene*. This latter mineral is quite a strong green in colour and feebly pleochroic. Between these three coloured constituents of the rock is a colourless interlocking, often quite granular, aggregate of *calcite*, *scapolite* and *microcline*, with possibly some orthoclase. The calcite is often seen

to be growing—evidently by replacement—at the expense of the felspar, but no evidence could be found that the scapolite had formed in a similar manner. It may be that the scapolite was formed when a pre-existing plagioclastic felspar was undergoing alteration. In one case, however, two plates, one of pyroxene and one of scapolite, are seen to interlock in a rather graphic fashion. This graphic interlocking is still better seen in places where one calcite individual is intergrown with another. The *quartz*, as usual, occurs at the boundaries of the calcite grains. *Sphene* is not very abundant, but where seen is idiomorphic with regard to the other minerals and, though usually colourless, is in places irregularly tinted pale brown.

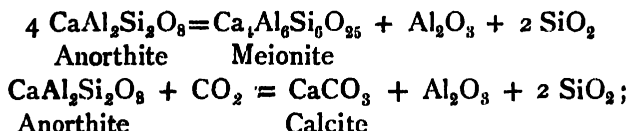
This and No. 30A, both collected by Mr. Datta, are the only rocks from this area in which I have found scapolite, the presence of which thus imparts a special interest to these specimens. It seems probable that this rock, like the other calciphyres, has been derived from a pyroxenic gneiss, but that in this case the chemical changes have proceeded along somewhat different lines.

To explain this modification it is only necessary to suppose that the alkaline waters, invoked to bring about the reaction given on page 172, contained also sodium chloride in solution, and that, as was no doubt the case, a plagioclastic felspar was originally present. The albite portion of the plagioclase was then converted into the marialite portion of the scapolite, thus:—



$$\underset{\text{Albite}}{3\ Na_2Al_2Si_6O_{16}} + 2\ NaCl = \underset{\text{Marialite}}{2\ Na_4Al_3Si_9O_{24}Cl};$$

and the anorthite portion into meionite and calcite, thus:—



$$\underset{\text{Anorthite}}{4\ CaAl_2Si_2O_8} = \underset{\text{Meionite}}{Ca_4Al_6Si_6O_{25}} + Al_2O_3 + 2\ SiO_2$$

$$\underset{\text{Anorthite}}{CaAl_2Si_2O_8} + CO_2 = \underset{\text{Calcite}}{CaCO_3} + Al_2O_3 + 2\ SiO_2;$$

the alumina formed by both changes being removed in solution as an alkaline aluminate and at least a portion of the silica left behind in the rock as the rounded quartz grains occurring at the boundaries of the calcite plates.

Group VIII.—The Crystalline Limestones.

For a sub-division of these into three classes see page 167. The origin of the various limestones has already been discussed on pages 168 to 171. Before passing to the detailed descriptions of these rocks it is as well to notice that they usually occur in bands which are never more than a mile or so long and often much less. The termination of these bands can, no doubt, often be explained by faulting, but it is probable that in at least some cases the bands of crystalline limestones die out in lenticular fashion. These limestones are very abundant and, though they often contain a profusion of accessory minerals arranged more or less in bands, would probably make handsome marbles should a demand for them arise.

To distinguish between calcite and dolomite it was found necessary to stain with Lemberg's solution all the microscope slides of the rocks of this group, and some of those of Groups VI and VII; as a result of this it was found that the means usually employed for distinguishing between these two minerals under the microscope do not hold for these rocks—as Lacroix also found 16 years ago with regard to the "cipolins" of Ceylon. The points usually emphasized are:—

I

(*a*) that dolomite characteristically shows a tendency to idiomorphism, usually having rhombohedral outlines, while calcite occurs in allotriomorphic and often interlocking grains;

(*b*) that dolomite is seldom or never twinned, while calcite usually is;

(*c*) that dolomite often or usually has a yellowish or brownish tint, and is frequently zoned, while calcite is customarily colourless;

(*d*) that the rhombohedral cleavages are more marked in calcite.

A clear summary of the work on this subject up to the year 1879 is given by Renard[1] in a paper in which he recognises all the above criteria[2], laying special stress on (*a*); he supports his data with

[1] "Des caractères distinctifs de la dolomite et de la calcite dans les roches calcaires et dolomitiques du Calcaire carbonifère de Belgique." *Bull. de l'Académie Royale de Belgique*, XLVII, No. 5, pp. 541-563, (1879).

[2] *Loc. cit.*, p. 557.

micro-chemical tests. Some recent references on the same subject are given in the footnote below.[1]

Taking the calcite and dolomite in rock No. 42 described below, it was found that:—

II

(*a*) these two minerals are usually allotriomorphic, sometimes, as in this rock, separated by well-defined curved boundaries; but in other cases they have interlocking junctions, while sometimes patches of calcite occur in the dolomite;

(*b*) the dolomite is much more frequently twinned than the calcite, and the hemitrope bands tend to be broader;

(*c*) the dolomite is usually clear and practically colourless; while the calcite is often clouded;

(*d*) the cleavages are usually more marked in the dolomite and more frequently shown, many calcite individuals being quite devoid of cleavage.

This latter set of distinguishing criteria agrees very well with those noticed by Lacroix[2] when dealing with the "cipolins" of Ceylon, some of which probably have a similar origin to the rocks described in this paper. The discrepancy between the two sets of criteria, I and II, is probably due in many cases, to a difference in origin of the dolomite considered. In the former case (I) the dolomite referred to is probably, more often than not, the result of the secondary change of calcite to dolomite by the agency of magnesia-bearing waters (in some cases those of the ocean), while in these Chhindwára and

[1] The letters after the following references show which of the above criteria are mentioned:—

Judd, *Phil. Trans. Roy. Soc.*, 187A, p. 206, (1896)—(*a*), (*b*).

Cole, "Aids in Practical Geology," 3rd edit., pp. 161, 206, 275, (1898).—(*a*), (*b*), *c*).

Rosenbusch-Iddings, "Microscopical Physiography of the Rock-forming Minerals," 4th edit., pp. 178—180, (1900)—(*a*), (*b*).

Harker, "Petrology for Students," 3rd edit., pp. 260, 261, (1902)—(*a*), (*b*), (*c*), (*d*).

Coomáraswámy, *Q. J. G. S.*, LVIII, pp. 403, 413, (1902)—(*a*).

Skeats, *Bull. Mus. Comp. Zoöl.*, XLII, pp. 65, 67, 111, 112, (1903)—(*a*), (*c*), (*d*).

Cullis, "The Atoll of Funafuti," *Royal Soc.*, p. 408, (1904)—(*c*).

Skeats, *Q. J. G. S.*, XLI, pp. 120, 128, 130, (1905).—(*a*), (*b*), (*c*).

[2] *Bull. de la Soc. Franç. Minéral.*, XII, 337-339, (1889); *Rec., Geol. Surv. Ind.*, XXIV, 191, 192, (1891).

Cingalese rocks the dolomite has been formed direct from a magnesian silicate and not by the alteration of previously existing calcite.

As a check upon these staining tests it should be mentioned that a very fine-grained limestone recently received in this office from Silyari (21°25′—81°49′) in the Raipur district, Central Provinces, and presumably of Vindhyan age, when stained showed idiomorphic rhombohedral zoned crystals (unstained) in a fine-grained matrix (stained). On treating with acetic acid a thin section of this rock placed on the stage of the microscope, bubbles of gas were seen to rise from the matrix, which was eventually dissolved leaving the rhombohedral crystals apparently unchanged. These latter were hence dolomite, the matrix being the calcite, so that in this case the minerals conformed with the set of criteria I rather than with II.

The moral of the above remarks is that unless the dolomite exhibit rhombohedral outlines, it is unsafe to decide from the microscopical aspects that a particular mineral in a thin section is either calcite or dolomite, until it has been decided by staining (or less conveniently by micro-chemical tests) what are the distinguishing characteristics of these two minerals in the particular set of rocks under examination.[1]

CLASS I.

This is the class which, as already explained, is regarded as being genetically connected with the calciphyres and quartz-pyroxene gneisses and in which dolomite is consequently absent (see p. 170).

[1] Since riting the above I have seen the method of distinguishing calcite from dolomite given by Dr. Luquer in his "Minerals in Rock Sections," pp. 62 and 64, (1905). Owing to the fact that the twinning-lamellæ of calcite and dolomite are parallel to the rhombohedra $-\frac{1}{2}R(01\bar{1}2)$ and $-2R(02\bar{2}1)$ respectively, the hemitrope bands are seen in thin sections to be roughly parallel to the longer and shorter diagonals, respectively, of the cleavage rhombs. I have applied this test to the Chhindwára crystalline limestones and find that by its means—when twinning-lamellæ and cleavages are both present and those sections are chosen in which the angles between the cleavages-traces are approximately those of the cleavage rhombs—it is often possible to decide whether a particular individual is calcite or dolomite; the result thus obtained agrees with the staining test. But as in these Chhindwára rocks only a small proportion of the calcite and dolomite individuals show both cleavage and twinning, this test is only of limited application.

No. 33.—16·940—4855—Crystalline Limestone—Alesur—G=2·72.

Due west of Devi, on the further side of the Ghondi Nála, is a low ridge of crystalline limestone about a furlong in length and manganiferous at its eastern end. The rock is a vertically-bedded, white to greyish-white, limestone of medium grain, containing lenticles of quartz up to 2 or 3 feet long and a foot across. The hand-specimen shows a little pale brownish and greenish mica, and some pale greenish patches of diopside, together with minute specks of sphene in the calcite. M.—Mostly rather large *calcite* plates with a fair quantity of small round *quartz* grains occurring at the junctions of the calcite crystals and partly baying into the latter, as is well shown in Plate 16, fig. 2. There are also occasional patches of very pale greenish *pyroxene* which is largely broken up by calcite. Included in the calcite are a fair number of very highly refracting grains of *sphene*, often spindle-shaped, with a very marked pleochroism from pinkish-brown, clove-brown or pink to very pale greenish. A few round *apatite* grains are also present.

No. 34.—16·945—4859—Crystalline Limestone with hornblende—Devi—G.=2·73.

This rock was found, on the top of the same hill as Nos. 30 and 37, as a band just to the north of the manganese-ore which occurs here in the crystalline limestones. It is a medium to coarse-grained rock of pinkish colour with irregular, striated, dark-green hornblende prisms in fair abundance. M.—Consists mostly of *calcite*, which is interesting because it shows the rhombohedral cleavage reversed in alternate twinning-lamellæ, a phenomenon which one would expect, but which for various reasons is not usually noticeable. The amphibole has extinction angles up to 18° referred to the prismatic cleavages. Its pleochroism is of the usual type, namely :—

$\mathfrak{a}$ = greenish-yellow,
$\mathfrak{b}$ = green,
$\mathfrak{c}$ = bluish-green,

and it is probably common *hornblende*. Besides a little *sphene* and a very little *quartz*, there is also a trace of *plagioclase* possibly the last remnant of a mineral which was once one of the chief constituents of the rock.

No. 35.—16·941 to 16·944—4856 to 4858—Crystalline Limestone (Calciphyre) with essonite—Bichua.

This rock crops out along the summit of the shoe-shaped spur of Burár Hill mentioned in connection with No. 23. It is separated from this hornblende-felspar-schist by an almandite-gneiss to be noticed later (No. 43). This interesting rock contains a great assortment of accessory minerals, which are arranged more or less in bands often weathering out one or even two inches from the rock. The most prominent mineral is the lime-alumina garnet, *essonite*, which occurs as resin-brown to cinnamon-brown rhomb-dodecahedra up to 1¼ inches in diameter. The faces of the crystals are never perfect, owing to the penetration of epidote and calcite into the mineral. For this reason a pure piece of the mineral could not be obtained; but as homogeneous a crystal as could be isolated gave a specific gravity =3·43, while another gave G.=3·26. One piece of the rock (16·944) showed a reddish-black garnet, orange-brown in small chips, with G.= 3·365. This, on testing, was also found to be essonite. The fractured surfaces of the garnets do not show the concentric structure which is so common with spessartite. The other minerals noticeable in hand-specimens are epidote in beautiful bright-green prisms, a pale-green asbestos-like mineral, flesh-red felspar, greyish-green pyroxene, and finally *calcite*, which forms the chief constituent and varies from pink to white in colour and the individuals of which are often nearly ½ inch in diameter. The specific gravity of the rock is very variable, depending on the proportion of minerals other than calcite, and ranges between 2·70 to 2·93 in specimens tested. M.—The *essonite* is zoned, brown inside and paler brown externally, and occurs in large patches including both *epidote* and calcite. The dark variety of essonite shows a terra-cotta colour with pale-brown bands and patches in places and also includes bright-yellow epidote. The asbestos-like mineral is seen to be *actinolite* in long thin crystals, but sparingly present. *Pyroxene* in pale-green granules, and often altering to carbonates, is observed to be frequently much intergrown with the *garnet*. The *felspar* is invariably so altered and opaque that it cannot be identified. Two other minerals requiring mention are *sphene* (spindle-shaped) and *quartz*, the latter being full of innumerable lineally arranged negative crystals containing liquid bubbles. The quartz also shows undulatory extinction.

CLASS II.

The manganiferous crystalline limestones of the Nágpur district owe their manganiferous character either to piedmontite, spessartite, or rhodonite; but piedmontite has not yet been found in the Chhindwára district, and the only examples of manganiferous limestones, occurring at Devi and Alesur, derive their manganiferous character from scattered grains of spessartite or rhodonite, which have become partially altered so that the accompanying calcite is blackened by the deposition along its cleavage and twinning planes of manganese-oxide, derived from these manganese-silicates. Thus there has been produced a black crystalline limestone which would form a fine black marble could any be found free from rhodonite and spessartite; for these two minerals, being of superior hardness to the calcite, prevent even polishing of the rock.

No. 36.—16·963—4876—Manganiferous Crystalline Limestone—Alesur—G. = 2·85.

Specimen No. 33 passes along the strike, on approaching the Ghondi Nála, into the rock under question, which, in its turn, passes into spessartite-quartz rock partially changed to manganese-ore. It is in all probability a case of a lenticular band of manganese-silicate rock included in the crystalline limestones and giving rise to a manganiferous variety of limestone at the junction of the two. The rock is rather coarse-grained and dark-greyish in colour; but in some parts it is whitish with yellow spessartite patches, and in other parts quite blackened. The calcite crystals are often distorted, *i.e.*, show curved faces. M.—The *calcite* plates form a coarse-grained aggregate and often have their twinning-lamellæ curved, besides exhibiting undulatory extinction. Abundant yellow *spessartite* grains are present, usually at the junctions of calcite crystals, but sometimes included right in them. There are also larger rounded individuals of *rhodonite* often intimately associated with the garnet. The rhodonite is evidently much more easily altered than the spessartite and is often completely converted into *manganese-ore*, while the garnet is either unaltered or has only suffered partial change. Besides *apatite* and *sphene* a little strained *quartz* is also present.

No. 37.—16·964—4877—Black Crystalline Limestone—Devi—G.=2·94.

A band of manganiferous rock which contains *spessartite*, rhodonite, *rhodochrosite* and *manganese-ores*, and which is intercalated between the crystalline limestones of the high hill east of Devi (see Nos. 30 and 34), gradually climbs up the northern slope of this hill to the top. The specimen was collected on the slope of the hill from the junction of this manganese-silicate band with the crystalline limestones. It is a coarse-grained black crystalline limestone in which abundant small grains of blackened *rhodonite* included in the calcite plates produce a lustre-mottling effect. These grains, as would be expected, stand out on the weathered surfaces. M.—The *calcite* in one slide is so impregnated with manganese-ore dust as to be unrecognisable, and includes round colourless highly refracting grains of *rhodonite* some of which are partially, and some completely, altered to manganese-ore. These correspond to the shining black specks in the hand-specimen. Another section shows that the blackening of the calcite is due to the deposition of manganese-oxide dust along both cleavage and twinning planes (Plate 17, fig. 1); the source of this manganese can be referred partly to the rhodonite in the specimen and partly to the neighbouring band of manganese-silicates and ores. Hence this rock, when fresh, was probably a pale-coloured crystalline limestone with scattered granules of rhodonite.

CLASS III.

For a discussion on the origin of the serpentinous crystalline limestones and cipollinos see pages 170 and 171. In support of the ideas there put forward, the rocks described below are taken to provide ample evidence. These rocks are very abundant in this district and the following important outcrops of them may be mentioned:—

1. Some hills in the Sitapár and Lakhanwára jungles.

2. In both the Gehra and the Budbuda Nálas, just above their junction.

3. The hills about one mile E. N. E. of Bichua village and situated partly in Bichua and partly in Alesur limits.

4. The stream-bed just east of Gowári Warhona village.

5. The large mass of hills and hillocks to the east and S. E. of Dudhára Kalán.

No. 38.—16·952—4866—Serpentinous Crystalline Limestone with a band of cream-coloured pyroxene—Gowári Warhona—G. = 2·73 (of the crystalline limestone.)

In a stream to the N. E. of the village is an outcrop of serpentinous crystalline limestones and from that outcrop this and the two following specimens were collected. The rocks at that place dip west at about 30°, this unusual direction being probably due to a fault. The specimen in question is of medium grain, banded white and greenish-yellow in colour, showing both calcite (white) and serpentine (greenish-yellow); but it also contains a cream-coloured band of pyroxene, of hardness 5 and G. = 2·99, upon which serpentine is encroaching in an irregular manner. This pyroxene is mainly one individual and has a tendency to pearly lustre. M.—A section cut from the junction of the creamy band and the limestone shows the former to consist of colourless *pyroxene* apparently passing into *tremolite* in parallel growth. This amphibole-pyroxene complex is traversed by veinlets containing either *serpentine* or rhombohedral carbonates or both (Plate 17, fig. 2), while the adjoining crystalline limestone is full of nests of serpentine; the whole suggests that the limestone containing serpentine is the final result of a process in which the pyroxene passes entirely into serpentine, calcite and dolomite, the colourless amphibole being possibly an intermediate product, though the change from pyroxene to serpentine and rhombohedral carbonates undoubtedly often takes place directly. A section cut from the crystalline limestone alone is similar to that of the rock next described, except that no mica is present.

No. 39.—16·951—4865—Serpentinous Cipollino—Gowári Warhona—G. = 2·74.

This rock, taken from the same exposure as the preceding, is of medium to coarse grain, banded with white, pinkish and green colours, and having also some micaceous films. M.—It consists of an interlocking mass of *calcite* and a fair proportion of *dolomite* with many rounded patches of *serpentine*, which are pseudomorphous after a previous magnesian silicate, probably pyroxene (Plate 18, fig. 1). Some remains of the original mineral indicate *pyroxene*, and the meshes of the serpentine are sometimes at right angles, and sometimes approach more nearly the angles required for amphibole.

This serpentine is very pale-yellowish in colour not revealing its real structure under a low power. Under a higher power the boundaries of the meshes are seen to be made up of fine fibres transverse to these boundaries, while the interior of the meshes is often isotropic. Another variety of serpentine, brownish by ordinary light, shows a structure suggesting that of olivine-derived serpentine. There is also some colourless mica, probably *phlogopite*, containing three intersecting sets of inclusions, the angles between which are not, however, 60°.

No. 40.—16·961—4875—Crystalline Limestone with a band of altered cream-coloured pyroxene—Gowári Warhona.

This rock, collected from the same exposure as the two preceding, is medium to rather fine-grained and reddish in colour; it also contains a 1-inch thick band of altered cream-coloured pyroxene, which can, in places, be scratched by the finger-nail and shows a laminated structure, probably parallel to the original basal parting of the mineral. M.—The larger portion of the cream-coloured band consists of large individuals of much altered colourless *pyroxene* in which alteration has taken place along planes parallel to the basal plane with formation of bands of a colourless low-refracting, finely laminated mineral, with low strength of double refraction; the polarization colours vary from first to second order, and this mineral is optically positive with regard to its length. Hence it is perhaps laminated *serpentine* or antigorite. These serpentinous bands alternate with other bands, some of which are *calcite*, whilst some contain remains of pyroxene.

No. 41.—16·954—4868—Serpentinous Crystalline Limestone with green spinel (?)—Sitapár—G.=2·86.

The outcrop of this rock is in a stream-bed a little more than a mile due north of Sitapár (Pángri).[1] It is a medium-grained rock showing greyish-white calcite, yellow-green oily-looking serpentine and some scattered small dark-green grains of spinel (?). M.—Shows unequivocally that colourless *pyroxene* (with extinction up to 38° on clino-pinacoidal sections) is changing to *calcite* and sulphur-yellow

[1] The "Seetapar" of the 1-inch map is non-existent, while the village marked as "Pangree" is really Sitapár and the hamlet half a mile N. of E. from the real Sitapár is the real Pángri. This mistake has been corrected on the accompanying map, Plate 20.

serpentine, the patches of the latter having very smooth and rounded boundaries. The serpentine often breaks up the pyroxene into patches, so that remains of pyroxene are seen in the midst of the serpentine (Plate 18, fig. 2). The calcite does the same thing so as to ophitically include the pyroxene. There is in addition some colourless *amphibole* (extinction-angle up to 18°) intergrown with, and sometimes surrounding, the pyroxene from which it has probably been derived. I could not, however, determine if the amphibole also changes into serpentine and calcite. Some clear round isotropic grains of pale-green colour are either *spinel* or garnet, more probably the former. This is a case in which the alteration process has proceeded entirely in accordance with equation (*a*) on page 171, for no dolomite whatever was found in the microscope section.

No. 42.—16·958—4872—Serpentinous Crystalline Limestone with chondrodite, spinel and phlogopite—Alesur—G.=2·83.

The locality for this rock is near the top of the most southerly hill within Alesur village limits. The hill is just to the S. E. of a straight line joining Bichua and Devi villages. The rock is a very coarse white crystalline limestone containing, scattered and in bands, pale-yellow-green serpentine, deep orange chondrodite, pale lavender-grey spinel, and pale-brownish mica. M.—The *chondrodite*[1] occurs in big patches broken up by yellow-brown serpentine, and is not uniform in colour. One portion of an individual will show the following pleochroism :—

direction of greater elasticity	=golden-yellow,
ditto lesser ditto	=slightly yellow (almost colourless),

while another portion will be quite colourless with possibly a little absorption. In one case bright-yellow chondrodite was colourless in the middle. The chondrodite has a high index of refraction and double refraction nearly as high as olivine. It also exhibits some well-marked straight cracks (? cleavages) with reference to which the extinction angle varies from 0° to 14°. These cracks are about at right angles to the serpentine strings.

[1] The word "chondrodite" is used in its customary general sense, as it has not been determined to which of the Humite group of minerals this particular example is to be referred.

Calcite and *dolomite* seem to be about equally abundant in this rock, plates of them often cutting across the chondrodite or occurring as patches in it. The criteria for distinguishing between these two minerals, given on pages 195 and 196, were derived chiefly from a study of this rock. The most important and useful of these distinctions is the clearness of the dolomite and the cloudiness of the calcite, this latter feature being due to abundant minute indeterminate particles with no definite arrangement. The photo-micrograph (Plate 19, fig. 1) shows both the calcite and the dolomite. Either of these may occur in direct contact with the chondrodite, which itself may be found entirely surrounded by either carbonate. Sometimes, however, serpentine separates the chondrodite from the rhombohedral carbonates. In the very similar rock from Ceylon described by Lacroix,[1] as suffering a similar alteration to serpentine and carbonates, the chondrodite was not pleochroic, neither was the dolomite seen in actual contact with the chondrodite, there being a separating "muff" (*manchon*) of calcite.[2]

Detached flakes of the mica give optic axial angles varying between 16° and 25° and show acicular inclusions arranged at angles of 60°. Hence this mica is considered to be *phlogopite*. This mineral, like the chondrodite, is seen to be giving place to dolomite with a smaller quantity of calcite and appears, preparatory to breaking up, to undergo some change by which its strength of double refraction ($\gamma - \alpha$) is much lowered, without affecting its other optical properties.

The *spinel* grains, which range up to $\frac{1}{16}$ to $\frac{1}{8}$ inch in diameter as seen in the hand-specimen, are observed under the microscope to be colourless, isotropic and of a higher refractive index than the chondrodite. It is very doubtful if any of the spinel be suffering alteration.

Since none of the minerals—chondrodite, spinel and phlogopite—constituting the original rock contain lime, this latter component of

[1] *Bulletin de la Société Francaise de Minéralogie*, XII, 338, 343, (1889). *Rec. Geol. Surv. Ind.*, XXIV, 192, 195, (1891).

[2] The suggestion of Coomáraswámy [*Q.J. G.S.*, LVIII, 420, (1902)] that the colourless chondrodite of Lacroix may possibly be olivine will not, even if correct, materially affect the case, owing to the fact that both minerals are silicates of magnesium, the chondrodite simply containing water and fluorine in addition; so that similar alteration products may be expected when these two minerals are subjected to similar alterative agents.

the altered rock must, together with the carbon dioxide, have been derived from external sources. The solutions thus hypothecated would also be required to remove the alumina from the altering phlogopite, but owing to the low percentage of silica in both chondrodite and phlogopite this latter constituent would probably all remain to form serpentine and, contrary to what happens when diopside undergoes similar changes (see page 171), would not be removed in solution.

Group IX.—Almandite-gneiss.

The only rock in this group—the one described below—would no doubt be in its most natural position in Group VII, as it is undoubtedly very closely related genetically to No. 35 of Group VIII. It does not, however, contain any pyroxene, or its paramorphic derivative, hornblende.

No. 43.—16·946—4860—Almandite-gneiss passing into a Calciphyre—Bichua—G.=3·14.

This is the rock mentioned (page 184) as occurring on the northern slope of the shoe-shaped spur of Burár Hill, between the essonite-bearing crystalline limestone (No. 35) on the south and the hornblende-schist (No. 23) on the north. Macroscopically it is a most striking rock, being medium to fine-grained, of flesh-pink and emerald-green colours due to felspar and epidote respectively, with deep purple-black spots due to garnets up to ¼ inch and more in diameter. There is also some white calcite. Qualitative tests show the garnet to be the iron-alumina-garnet, *almandite*. M.—Garnet is very abundant, irregular in shape, of a rich brown colour, and is often surrounded by yellow *epidote* in large plates. The special interest of this rock lies, however, in what may be called the matrix in which the above are set. This interstitial matter is often a micrographic intergrowth of *calcite* and *quartz* frequently enclosing much kaolinized cores of *plagioclase* from which this micro-pegmatite has probably been derived, as explained on page 172 (Plate 19, fig. 2). The plagioclase is usually so clouded as to be indeterminate, but the few examples in which the albite twinning was visible indicated a composition at least as basic as andesine. The calcite is usually untwinned. Besides a little *microcline* there is an abundance of idiomorphic wedge-shaped *sphenes* enclosed in every-

thing else except the garnet in which they are very rare. *Apatite* is also present together with an *iron-ore,* either magnetite or ilmenite.

Regarding the calcite and quartz, and perhaps the epidote, as secondary, we may look upon the original rock as having been composed of almandite, and basic plagioclase, with abundance of sphene and some microcline, apatite and iron-ore. Comparing this with the list of minerals given on page 189 as occurring in the quartz-pyroxene-gneisses, we observe a general consanguinity between these two rocks, with the difference that the almandite-gneiss is probably a more basic one (*cf.* the specific gravities) in which quartz is absent—or if present, only sparingly so — and microcline less abundant, and in which, instead of pyroxene, there is a great development of the garnet element. A characteristic of both rocks is the formation, by chemical change involving the introduction of carbon dioxide, of secondary calcite and quartz, while in both rocks epidote is very abundant and, though considered on page 188 as of probable secondary origin in at least some cases, it must be noticed that in none of the rock-sections examined has any certain evidence of the secondary nature of this epidote been obtained, while in more than one case the epidote has shown patches of various shades of brown suggesting *allanite.*

Group X.—Manganese-bearing Rocks and Ores.

Beyond the mere enumeration of the various types mentioned on page 168, and the few remarks given on pages 172 and 173 as to the mode of occurrence and origin of these rocks, it is not proposed to say anything regarding this group, as it is intended to include a description of these types in a subsequent paper dealing with all the Indian rocks of similar nature. A brief description, however, will now be given, in the next chapter, of each of the manganese-ore deposits of this area—the only part of the Chhindwára district in which such rocks are at present known to occur.

V.—THE MANGANESE-ORE DEPOSITS.

It should be mentioned that Mr. Datta in his 1893-4 survey of this area discovered the deposit of Kachi Dhána, and also found indications of that of Gowári Warhona. Subsequently, in the year 1903, the late Mr. A. M. Gow Smith independently found all the deposits mentioned

below with the exception of Alesur and Devi, of which the last named was discovered by Rai Sahib Mathura Prasad of Chhindwára.

The deposits may be arranged geographically from north to south in the following order :—

(1) Kachi Dhána.
(2) Lakhanwára.
(3) Gaimukh.
(4) Sitapár.
(5) Bichua.
(6) Alesur.
(7) Devi.
(8) Ghoti.
(9) Wagora.
(10) Gowári Warhona.
(11) Dudhára.

In this order they will now be briefly described. Numbers corresponding to these deposits will be found on the map (Pl. 20). Of the above deposits Nos. 1 and 10 are most certainly worth working, as is probably No. 4. Nos. 2 and 3 will need some development work before a definite opinion can be expressed, while the remainder, with the possible exception of No. 8, can be condemned at once, as not having the slightest value whatever under present conditions. Owing to their distance (30 to 50 miles) from the railway, none of these deposits have yet been opened up.

With regard to the frequent use of the word *spessartite* in this paper, it is necessary to say that the only quantitative analysis made (of a specimen from the Nágpur district) shows that the mineral in that case is spessartite, and that the similar mode of occurrence and crystalline habit (trapezohedral) of the manganese-garnets of the Central Provinces render it very probable that in the majority of cases they fall under the species spessartite; their varying colour, ranging from yellow through orange to orange-red, is probably partly due to a varying percentage of iron.

The analyses given below under the headings of the separate deposits are mostly taken from the reports on these properties made by Messrs. H. Kilburn Scott and W. Selkirk respectively, and are published with the kind permission of the directors of the Indian Manganese Company on behalf of which the reports were made.

Since this paper was sent to the press the results of the analysis of the samples taken by the author have been received. The samples were collected by breaking off pieces at regular intervals along the outcrop of the manganese-ore *in situ.* Where the outcrop was obviously unworkable, owing to the presence of large amounts of free quartz or spessartite-bearing rock, it was not sampled, because in working the deposit such rock, if quarried, would be thrown on the waste-heap. In cases where any ore had been quarried some of it was added to the sample. It being now too late to intercalate the analyses in their proper places, they are all placed together in the following table and should be compared with the other analyses scattered through this section of the paper:—

	Kachi Dhana.	Lakhanwára.	Gaimukh.	Sitapár.	Sitapár.	Devi.	Ghoti.	Wagora.	Gowári Warhona.
Number of Sample.	9	11	12	10	10A	13	14	8	7
Manganese	54·73	50·41	54·98	54·97	54·57	48·95	49·55	29·08	53·59
Iron	5·00	11·77	6·19	6·89	7·03	7·03	7·71	6·88	5·00
Silica	6·99	4·86	10·63	6·95	7·90	4·98	8·74	36·63	6·21
Phosphorus	0·07	0·20	0·04	0·06	0·12	0·28	0·28	0·15	0·07
Moisture (at 100° C.)	0·17	0·39	0·32	0·00	0·04	1·27	0·52	0·86	0·31
Baryta	0·98	...	...	...	...	...	...	...	...
Arsenic oxide (As_2O_5)	...	...	...	0·003	...	...	...	...	...
Carbon dioxide	...	0·14	0·14	...	...	0·04	...	...	...

The above results were furnished by the Director of the Imperial Institute, London, to whom the samples were sent through the Officiating Reporter on Economic Products, Calcutta.

1. Kachi Dhana.

This is undoubtedly the largest and most valuable deposit in the district. There are five separate ore-hillocks, arranged along an E.—W. line, of which the largest is about 360 paces long, 130 broad and, say, 40 feet high. As far as can be estimated without clearing away the thick jungle which covers the hill and opening up the deposit, the ore-body will probably

be found to be from 50 to 100 feet wide. The ore varies slightly in character in the different hillocks and is either a fine to medium-grained mixture of *psilomelane* and *braunite* in which the latter is the predominant constituent or is finely crystalline braunite with fairly numerous black spots. Associated with the ores is the usual *spessartite-quartz* rock, and sometimes *magnetite*-spessartite rock, both of which have in places been partly chalcedonized. In one of the hillocks was found a very interesting granular rock—16·966—of white *felspar* with scattered brownish-orange grains giving a slight manganese reaction. Under the microscope this mineral is seen to be *pyroxene* showing pinkish-brown to pale greenish-brown pleochroism. The felspar is microcline, orthoclase, and albite, and the rock is probably intrusive.

There is no doubt that when worked this deposit should yield a large amount of ore, which to judge from various analyses should range well over 50 per cent. manganese. An assay of a small specimen collected by Mr. Datta yielded :—

	Per cent.
Manganese	53·25
Phosphorus	·91
Moisture	·26

The phosphorus content is, of course, much too high, but eight other analyses made both on large samples and on hand-specimens taken by Messrs. Kilburn Scott and Selkirk showed results ranging between the following limits :—

Dried at 212° F.

	Per cent.
Manganese	53·05 to 56·82
Iron	2·82 „ 5·30
Silica	1·10 „ 9·02
Phosphorus	0·004 „ 0·135

While another which yielded :—

Dried at 212° F.

	Per cent.
Manganese	51·87
Iron	4·92
Silica	16·27
Phosphorus	0·033

was of a hand-specimen containing some glassy quartz.

2. Lakhanwara. Situated 200 to 250 yards west of the Gaimukh ore-body, this deposit is only visible at the surface as three very small outcrops of rather fine-grained, hard grey crystalline ore which is probably the best quality *braunite.* The following is an analysis of a sample taken by Mr. Scott :—

Dried at 212° F.

	Per cent.
Manganese	57·51
Iron	6·02
Silica	4·63
Phosphorus	0·153

3. Gaimukh. The outcrop of this ore-body is of lenticular shape, about 60 paces long and 26 broad, the lens being orientated east and west. The ore, which is mostly *braunite* with some *rhodochrosite*, has probably been derived from a rock consisting largely of *spessartite* of orange-yellow colour and of *rhodonite*, but it is only the central portion of the outcrop about 20 yards long and 7 broad which has undergone sufficient alteration to be workable as a source of ore. The following analyses are of samples taken from the outcrop, rejecting any pieces of ore that looked siliceous :—

Dried at 212° F.

	Mr. Scott.	Mr. Selkirk.
	Per cent.	Per cent
Manganese	56·68	54·20
Iron	6·21	5·00
Silica	7·68	9·75
Phosphorus	0·078	0·036

4. Sitapar.[1] This ore-deposit takes the form of a small elliptical hillock 27 paces long from east to west by 23 broad and perhaps 20 to 25 feet high. Since it rises from the middle of a field, it may be found to be of much greater extent on removing the surrounding alluvial soil. The whole outcrop consists of huge blocks containing a variety of manganese minerals of such u nusual

[1] See also *Rec. Geol. Surv. Ind.*, XXXIII, 232, 1906.

character and special interest that any description must be deferred till they have been worked out. The following are analyses of samples taken over the whole outcrop :—

Dried at 212° F.

	Mr. Scott.	Mr. Selkirk.
	Per cent.	Per cent.
Manganese	54·94	53·90
Iron	5·28	6·10
Silica	7·33	8·37
Phosphorus	0·072	0·055

5. Bichua.

A little to the south of the essonite-bearing crystalline limestones described above (p. 199) occurs a parallel band composed mainly of *spessartite-quartz* rock, with some *rhodonite* towards the eastern end. The outcrop takes the form of five hillocks, in which the garnet is often much altered, but never sufficiently so to constitute an ore. In places the rock becomes very quartzose, and in such cases the spessartite is crystallised in well-formed trapezohedral crystals of various shades of orange and red-brown to black. It is at the west end of this band that the spessartite-pegmatite, No. 12, occurs.

6. Alesur.

The manganiferous rock here is the outcrop mentioned in the description of the manganiferous crystalline limestone (No. 36). The length of manganiferous rock is 52 paces and at the eastern end, on reaching the Ghondi Nála, it is cut off by a complex of pegmatite injecting in all directions a garnet-bearing biotite-gneiss ; a little way from its eastern end the band reaches a maximum width of 5 or 6 yards. This deposit, like the preceding one, has no economic value.

7. Devi.

The ore here, originally discovered by an agent of Rai Sahib Mathura Prasad of Chhindwára, occurs as a band, traceable at intervals for about a mile, on the north side of a line of small hillocks of crystalline limestone and calciphyre, which terminates to the east in a hill over 150 feet high up the north side of which the ore-band gradually climbs to the top

(see No. 37). The strike is that of the crystalline limestones, averaging east and west, while the dip, as taken in the associated rocks, is at the west end of the outcrop steep to the north side and at the east end 25° to the south. The ore is either soft or hard, brownish-black in colour, and the result of the alteration of the *spessartite* and *rhodonite* which occur in lenticular bands in the limestone. Here also, as at Gaimukh *rhodochrosite* occurs, though in smaller quantity. The rock is only altered in places to any large extent, and a coarse and very beautiful rock of pink rhodonite and orange spessartite is rather common. Adjoining the ore-band the limestone is often blackened, for which see the description of No. 37. This is another of the deposits which probably have no economic value.

8. Ghoti.

Situated within the limits of the now non-existent village of Bharkum, this deposit consists of two parallel bands of *spessartite-quartz* rock with *rhodonite*, striking E. 10° N. and at the west end rising to form a low mound. The country-rock is mica-schist and a very schistose gneiss. The large proportion of fresh manganese-garnet and rhodonite, and the phosphoric nature of the ore, probably render the deposit valueless under present economic conditions. The following are analyses of samples of the best looking ore:—

Dried at 212° F.

	Mr. Scott.	Mr. Selkirk.
	Per cent.	Per cent.
Manganese	48·62	49·48
Iron	8·17	8·25
Silica	6·28	4·60
Phosphorus	0·276	0·306

9. Wagora.

The rocks here are chiefly biotite-garnet-granulites, -gneisses and -schists with a general strike of about W. 35° N. and an average dip of 60° to the south side. At least six parallel bands of *spessartite-quartz* rock, sometimes containing *rhodonite*, have been found intercalated in the above rocks, the thickness of the bands varying from 15 inches to 60 yards. In only

two places has the silicate-rock been altered to any extent to manganese-oxides, namely, at the places marked A and B respectively on the map, but in neither case can the deposit be considered to possess any commercial value.

10. Gowari Warhona.

In the season of 1893-4, Mr. Datta found indications of this deposit in the shape of pieces of ore scattered on the surface. Then, in 1903, the late Mr. Gow Smith opened up a series of trial pits exposing a stratum of good manganese-ore occurring in biotitic schists and acid gneisses. The ore stratum is 5½ to 6 feet thick, dipping at 50° to the S. 30° W., and is well exposed in two rivulets where it very closely simulates a coal outcrop, the ore being "bedded" or laminated in layers one to four inches thick. The total length of merchantable ore exposed is about ¼ mile; outside these limits the band becomes, to the south-east, rich in *spessartite* and *quartz*, and in both directions is probably cut off by faults bringing in calciphyres and limestones. Six analyses made for the Indian Manganese Company of both samples and hand-specimens gave the following limits:—

Dried at 212° F.

	Per cent.
Manganese	51·82 — 56·45
Iron	1·31 — 3·83
Silica	1·45 — 10·1
Phosphorus	0·03 — 0·09

and demonstrate amply that the deposit is well worth working; while one other sample gave:—

Dried at 212° F.

	Per cent.
Manganese	47·45
Iron	3·55
Silica	13·65
Phosphorus	0·122

11. Dudhara.

On the south-east side of "Dudara H" of the 1-inch map are two bands of *spessartite-quartz* rock, both much too fresh to be of any commercial value. The strike is south-east in a country-rock of soft biotite-gneisses and -schists. The more south-westerly of the two bands is very interesting, as it is a good example of lenticular thickening and thinning of bands of spessartite-quartz rock.

VI.—LIST OF MINERALS.

The following is a list of the minerals noticed in this area. (*m*) signifies that the mineral has only been noticed in microscope sections:—

Oxides :—

Quartz ; rock-crystal ; rose-quartz ; milky quartz ; chalcedony ; agate ; opal.

Martite ; spinel ; magnetite ; ilmenite (m) ; braunite ; rutile (m) ; pyrolusite ; psilomelane.

Carbonates :—

Calcite ; dolomite ; ankerite (?) ; rhodochrosite.

Silicates :—

Felspar Group.—Orthoclase ; microcline ; albite ; oligoclase (m) ; andesine (m) ; labradorite (m) ; perthite.

Pyroxene Group.—Diopside ; augite ; rhodonite ; manganese-pyroxene of Kachi Dhána.

Amphibole Group.—Tremolite ; actinolite ; hornblende ; uralite (m).

Garnet Group.—Essonite ; almandite ; spessartite ; andradite.

Scapolite Group.—Common scapolite (m) ; meionite.

Idocrase (m)?

Zircon (m).

Kyanite.

Epidote Group.—Zoisite (m)? ; epidote ; allanite (m).

Chondrodite.

Tourmaline.

Stilbite.

Mica Group.—Muscovite ; biotite ; phlogopite.

Chlorite.

Serpentine.

Green Earth.

Titano-silicates :—

Sphene (m).

Phosphates :—

Apatite (m).

Several other minerals mostly containing manganese have also been found, but not yet determined.

VII.—SUMMARY.

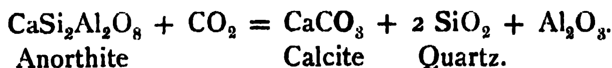
1. The main object of this paper is to put on record petrological descriptions of certain types of rock—chiefly of the metamorphic and crystalline series—found in the Sausar tahsil of the Chhindwára district. In the same field-season (1903-4) many of these rocks were also found to occur in the Nágpur, Bhandára and Bálaghát districts of the Central Provinces, and they will probably be found to have a still wider extension when a more detailed examination of the crystalline and metamorphic rocks of other districts is carried out.

2. Besides the descriptive work some remarks are also made on the origin of the calciphyres and crystalline limestone. The evidence regarding the calciphyres (Group VII) and the crystalline limestones of Group VIII, Class I, is held to justify the deductions :—

(*a*) that the crystalline limestones have been derived by chemical change—involving the introduction of carbon dioxide—from rocks either identical with or similar to the quartz-pyroxene-gneisses found in this area, the calciphyres representing the intermediate stage between the gneisses and the crystalline limestones ; and

(*b*) that the chief source of the lime of the calcite has been the plagioclastic felspar of the parent rock, though in some cases it may have been partly derived from external sources.

It is suggested that the change has taken place in accordance with the following equation :—

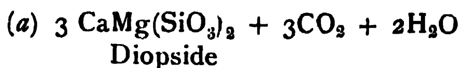


$$CaSi_2Al_2O_8 + CO_2 = CaCO_3 + 2\ SiO_2 + Al_2O_3.$$

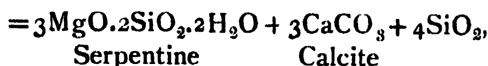
Anorthite   Calcite   Quartz.

Such a change could have been brought about by the permeation of the rock by waters containing carbon dioxide and an alkaline carbonate, the latter removing the alumina (see pages 168 to 170, 172).

3. The serpentinous crystalline limestones and cipollinos, on the other hand, are considered to have been derived from various calcium- and magnesium-silicate rocks composed chiefly of a white pyroxene, with or without phlogopite, although in one case chondrodite takes the place of the pyroxene. Assuming the pyroxene to be diopside, it is shown that the introduction of waters containing carbon dioxide would involve the formation of serpentine, calcite, dolomite and silica, the latter being removed in solution. The equations would be :—

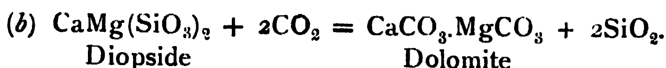


(*a*) $3\ CaMg(SiO_3)_2 + 3CO_2 + 2H_2O$
Diopside



$= 3MgO.2SiO_2.2H_2O + 3CaCO_3 + 4SiO_2,$
Serpentine Calcite

and



(*b*) $CaMg(SiO_3)_2 + 2CO_2 = CaCO_3.MgCO_3 + 2SiO_2.$
Diopside Dolomite

The colourless amphibole often observed with the diopside may be an intermediate product which was formed under certain conditions during the conversion of the latter into serpentine. The phlogopite, equally with the pyroxene, sometimes shows an alteration to dolomite and calcite, the source of the lime being then, in at least one case (No. 42), external (see pages 170, 171 and 201 to 206).

4. As the result of staining rock-slices with Lemberg's solution to distinguish between calcite and dolomite it was found that even in this particular set of rocks there are no constant criteria for discriminating between these two minerals, but that, on the whole, in the serpentinous limestones and cipollinos—the only rocks in this area in which dolomite has been found—the chief points are :—

(*a*) both minerals allotriomorphic, often interlocking with irregular boundaries; but dolomite occasionally moulded on to rounded calcite;

(*b*) dolomite usually twinned; calcite more often untwinned;

(*c*) dolomite usually clear and colourless; calcite often clouded;

(*d*) dolomite with well-marked cleavages; calcite with less marked and less frequently shown cleavages.

These criteria agree with those deduced by Lacroix when examining the crystalline limestones of Ceylon, but are almost the exact reverse of the usually recognized points of distinction (see pages 195 and 196).

5. A brief account is given of the mumerous cases of superficial replacement by silica of the Lametas (Cretaceous), metamorphic and crystalline rocks—the rocks observed to be thus silicified being Lameta limestone, crystalline limestone, gneiss, pegmatite, and spessartite-quartz rock. The phenomenon is explained as being probably due to the same agency as infilled the geodes in the Deccan Trap that once covered this whole area—that agency being obviously the mineralized waters with which the trap was saturated at the time of its eruption. As a less probable explanation of the change, attention is drawn to the fact that the formation of the serpentinous limestones (*vide* paragraph 3, *supra*) involves the removal of silica in solution (see pages 173 to 175).

6. The classification of the metamorphic and crystalline rocks, given on pages 166 to 168, is somewhat empiric, but it is to some extent based on genetic relationships. The various types of rock mentioned in this classification are then described in corresponding order. As rocks of special interest attention may be drawn to the following:—No. 23, a hornblende-schist containing presumably original pyroxene, thus indicating that the amphibolites and hornblende-schists of this area were originally pyroxenic igneous rocks; No. 37, a black manganiferous crystalline limestone which owes its colour to the deposition of manganese-oxide dust along the cleavage and twinning planes of the calcite; No. 43, an almandite-gneiss in which basic plagioclase is seen passing into a micropegmatite of calcite and quartz by a process like that mentioned in paragraph 2 above (see pages 184, 201 and 206).

7. Only a brief mention is made of the various types of manganiferous rocks, enumerated under Group X of the classification, as an opportunity to do so will, it is hoped, occur elsewhere (see pages 168, 172 and 207).

8. Short descriptions, however, are given of the various deposits of manganese ore—eleven in number—known to occur in this area, as several of them are of economic importance (see pages 207 to 214).

9. Finally there is added a list of the minerals found in this area (see page 215).

VIII.—GEOGRAPHICAL INDEX.

When the orthography of place-names as adopted in this paper differs considerably from that of the map (Pl. 20), then the latter spelling is also given in brackets.

	Latitude, N.		Longitude, E.[1]	
Alesur (Aleysoor)	21°	43′	78°	56′
Bharkum (Bundkoomb)	"	38½	"	56
Bichua	"	42	"	54½
Badbada N. (nála)	"	45	"	54
Burár Hill	"	43	"	55
Devi (Davee)	"	42½	"	56½
Dudhára Hill (Dudara H.)	"	30	"	56
Dudhára Khurd (Doodala Khoord)	"	30	"	56
Dudhára Kalán (Doodala Kulan)	"	30½	"	56
Gaimukh	"	45	"	53½
Gehra N.	"	44½	"	53½
Ghoda Hill	"	35	"	51
Ghondi N.	"	43	"	55½
Ghoti	"	38	"	55
Gowári Warhona (Gowaree Wandona)	"	31½	"	52
Kachi Dhána (Kuchee)	"	43½	"	50
Kanhán River	"	37	"	53½
Kára Hill	"	41	"	56
Kásigondri Hill	"	40	"	55
Khairi (Khyree Burosa)	"	41½	"	56½

[1] These longitudes are those given on the Standard Sheet (Plate 20) accompanying this paper, the scale being 1″=1 mile. They are greater by about one minute than those given in the corresponding Atlas Sheet (scale 1″=4 miles); hence, to convert them to longitudes of the Atlas Sheet, add one minute (1′).

	Latitude, N.		Longitude, E.[1]	
Khairi (Khyree Tygaon)	21°	32′	78°	52′
Khairi Nála	,,	32	,,	52
Kodadongri	,,	31	,,	54
Lakhanwára	,,	45	,,	53½
Lakhanwári	,,	46	,,	53½
Oopaea N.	,,	43	,,	54
Pángri	,,	44½	,,	55
Paumondi N.	,,	44	,,	49½
Rámakona (Ramakot)	,,	43	,,	53
Ránpet	,,	43	,,	51½
Sáhanwári	,,	40½	,,	58
Sárha Hill (Sarda H.)	,,	33½	,,	56
Sausar (Saosur)	,,	39½	,,	50
Sitapár	,,	44½	,,	54½
Utikáta (Ooteykata)	,,	41	,,	55
Wagora	,,	36	,,	51

[1] These longitudes are those given on the Standard Sheet (Plate 20) accompanying this paper, the scale being 1″ = 1 mile. They are greater by about one minute than those given in the corresponding Atlas Sheet (scale 1″=4 miles); hence, to convert them to longitudes of the Atlas Sheet, add one minute (1′).

NOTES ON THE GEOLOGY OF PARTS OF THE VALLEY OF THE KANHAN RIVER IN THE NAGPUR AND CHHINDWARA DISTRICTS, CENTRAL PROVINCES. BY P. N. DATTA, B. SC. (LOND.), F.G.S., *Deputy Superintendent, Geological Survey of India.* (With Plate 21.)

Area under notice.

THE area which forms the subject of the present paper includes part of the district of Nagpur and part of Chhindwára, being in fact that part of the valley of the Kanhan River which may be defined as between Kelod, Baraigaon and Bhewgarh, in Nagpur, on the south (lat. 21° 27′ N.), and Deogarh and Mokhair in Chhindwára, on the north (lat. 21° 52′ N.)[1]

Rocks met with in the area.

For a varying distance on either side of the Kanhan River the metamorphics are exposed, and are thus seen to occupy the lowest ground in the valley. The next higher group of rocks resting on the metamorphics are the Lametas or Infratrappean beds, while the rocks that overlie the Lametas are the basaltic or Deccan trap. This last constitutes the capping of the hills that overlook the valley and thus forms the highest ground here.

Thus we have three groups of rocks in this valley, namely, the Deccan trap, the Infratrappean or Lameta beds and the Metamorphics, the last group being the oldest of the three.

The Metamorphics.

The metamorphic rocks met with in this area comprise crystalline limestone and calcareous schist, quartz and quartzites, mica-schists, pyroxenic gneisses and calciphyres, pegmatite and gneiss.

Boundary of the Metamorphic area.

The ground to the south had previously been examined and mapped as far as the foot of the hills encircling Kelod on the north.[2] Commencing then by the *talao* of Jaithgarh (lat. 21° 28′, long. 78° 57′), by which are

[1] These notes were the result of a visit to the ground during the early part of season 1893-94, when the area was mapped, previously to proceeding to the district of Bhandara.

[2] W. T. Blanford, *Mem. Geol. Surv. Ind.*, IX, 295—330, (1872), with a map.

exposed thin-banded quartzites and soft micaceous schistose rocks, dipping S. 12° W. at 30°, there is a small outlier of the basaltic trap between this tank and the village of Kowtha (21° 28′, 78° 58′) entirely surrounded by the metamorphics. The basaltic cap with a thin fringe of the Lametas exposed on the low range of hills just north of the tank terminates at a short distance north-east of the tank and the boundary of the metamorphics runs from here west by north along the foot of the range until the cartroad between Kelod and Satnur (21° 31′, 78° 54′) is reached. From here the boundary keeps a north-westerly course passing by Tinkhera (21° 33′, 78° 52′), Borgaon (21° 34′, 78° 52′), Wagora (21° 35′, 78° 51′), Sausar (21° 40′, 78° 51′), Kudum (21° 41′, 78° 52′) and Nandia (21° 45′, 78° 49′). On either side of the Nakta by Deogarh (21° 52′, 78° 46′), the trap appears again, forming also the high ground on the south-east, whereon stand Ambajhiri (21° 50′, 78° 54′) and Teliadeo (21° 48′, 78° 52′). Further south-east, there are a couple of trap outliers by Devi (21° 42′, 78° 57′). In the south-eastern extremity of the area under notice also occur a few outliers of trap, as by Pathar (21° 31′, 79° 8′), and Bouli (21° 34′, 72° 8′), N.-W. of Bhewgarh (21° 29′, 79° 14′).

The metamorphics are inclined at a pretty high angle, the beds being in places nearer the vertical than otherwise.

Rocks : Mica-schists.

The rocks oftenest met with are the mica-schists, sometimes massive, but generally softish and in thin bands. Quartz also abounds, like the quartzites, and it is often by the presence of quartz and quartzite alone that one can detect the presence of metamorphics in ground otherwise covered. There is also seen in this area a fair amount of crystalline limestone. Of this crystalline limestone, there are three good exposures here. One of these lies close south-west of Taimurdoh (21° 30′, 79° 0′). The limestone here is thoroughly crystalline, of a light greyish colour and in fairly thick beds, forming most of the low hills between Taimurdoh and Dudhara (Doodala) (21° 31′, 78° 57′).

Quartz and Quartzites.

Crystalline limestone.

Another mass of crystalline limestone occurs north-east of the last outcrop and is well seen by Maharkund (21° 31′, 79° 2′) and south of Rajegaon (21° 33′, 79° 1′). The rock is of a beautiful pink colour, as well exposed on the stream bed south of Rajegaon, but the rock is rendered schistose by the development of minute flakes of mica,

A third band of a thick-bedded, light yellowish grey, crystalline limestone crops out by Ambajhiri (21° 50′, 78° 54′) and Pardi (21° 31′, 79° 10′).

Besides these three outcrops which are of fair extent and thickness, small calcareous bands are also visible, as in the neighbourhood of Satnur (21° 31′, 78° 54′), Sugum (21° 32′, 78° 57′), etc.

Quartz-pyroxene-gneiss and calciphyres.

The only noticeable exposures of what were regarded in the field as dioritic rocks and since determined [1] to be quartz-pyroxene-gneisses and calciphyres, are those near Poreyghat (21° 32′, 78° 58′) and Maindi (21° 34′, 78° 57′) and east by north of Kurmakra (21° 40′ 78° 54′).

Gneiss.

Close north and north-west of Lodhikhera village occur some thin outcrops of gneiss; the exposure on the stream-bed on the northern side of the village being of a pinkish colour from presence of pink-coloured felspars, the rock itself being well-foliated and composed chiefly ot pink felspar, quartz and mica.

Another very narrow band of gneiss is seen a little south of Kajalwani (21° 41′, 78° 54′), but here the outcrop is very limited and ill-exposed. The rock is well foliated.

A third outcrop of a granitic gneiss is visible in the northern extremity of the area, near Mahuldura (21° 47′, 78° 51′). The rock here is dark and fine-grained, composed of biotite, felspar and quartz, but with an ill-developed foliation.

Structure.

By Jaithgarh *talao* (21° 28′, 78° 57′) (at the south-western extremity of the area under consideration) the schists strike west by north and east by south, with a dip to the south, while by Maleygaon (21° 31′, 78° 59′), a few miles to the north, the dip is reversed. Following the beds north-eastwards the dip again changes to south by west as shown by the calcareous schists exposed near Maharkund (21° 31′, 79° 2′). North from Maharkund as well as east and north-eastwards from it, as far as the limits of the area under notice, the same dip (*i.e.*, to south by west) seems to prevail. By Lodhikhera (21° 35′, 78° 55′) the dip is south-west, but in proceeding north from here the dip becomes reversed, *i.e.*, north by east, as seen by the dip of the schists by Ramakona

[1] By Mr. Fermor. See pages 191 and 193 of the preceding paper.

(21° 42′, 78° 54′). In proceeding up the valley from Ramakona towards Khapa (21° 46′, 78° 50′), the dip becomes southerly again. Thus in passing from the southern limits to the northern extremity of the area, we find that the schists have been thrown into sharp anticlinal and synclinal folds, the axes of which have remained more or less parallel to one another. Hence the metamorphics are seen to exhibit one general direction of the strike, *viz.*, W. by N. to E. by S., pretty constantly all over the area, with of course local variations.

Ground much covered.

Over a considerable portion of the valley the rocks are more or less covered up with alluvium or soil of cultivation. Hence it becomes difficult from this prevalence of alluvium and cultivation to get, to any considerable extent, continuous exposures of rocks for purposes of examination, a circumstance that renders it difficult to identify the beds of the different flexures or trace them over any considerable distance.

Metamorphics to be classed with the Bengal Gneiss.

From the gneiss, that is, what little of it is seen in the area, being well foliated and its being interbedded with mica-schists, which constitute the prevailing rock, and from the presence of crystalline limestone, there can be little doubt that the metamorphics of this part of the country must be classed with the rocks formerly grouped as the Bengal gneiss (Manual, 2nd Ed., p. 30).

The Lametas.

Resting horizontally on the upturned and denuded edges of the metamorphic rocks, and conformably overlain by the basaltic trap, occurs a thin group of rocks to which the name of " Lametas " has been applied. These are exposed wherever the bottom of the basalt is seen : thus all along on either side of the valley a fringe of the Lametas is seen bordering the valley, and also wherever an outlier exists, resting on the metamorphics below and overlain by the basalt.

The most persistent constituent of the group, so far as the present area is concerned, is a calcareous rock varying from a grey pure limestone to cherty, sandy and gritty varieties. The limestone is associated with, and in places entirely replaced by, sandy or gritty beds.

Just north of the Jaithgarh *talao* (21° 28′, 78° 57′) (on the south-western extremity of the area), the Lametas are represented by a white coarse grit, somewhat calcareous, the constituents being mostly white quartz with some reddish quartzitic fragments and the calcareous

character of the rock being in some places more obvious than in others. But some distance north-east of this point the rock is a light grey limestone, almost pure. In the little bay-shaped valley due south of Satnur (21° 31′, 78° 54′), there is a wider exposure of the grey limestone, with an underlying calcareous arenaceous band, but the entire thickness of the group is not visible. About a mile west by south of Lodhikhera (21° 35′, 78° 55′), the hill-slopes and spurs show about 10 feet of the limestone resting almost horizontally on the schists and overlain by a dark basalt with acicular crystals of felspar. The limestone is light yellowish to grey, very cherty and with grains of white quartz disseminated in it in places. The limestone seems to constitute the whole of the Lametas here, there being no indications of an arenaceous or gritty band beneath the limestone. About 3 miles west by south of Lodhikhera, at the foot of the hills, is seen a white gritty sandstone. This underlies the limestone and forms the bottom rock of the group, but the thickness of the sandstone band is nowhere exposed here. Another fairly good exposure of the Lametas occurs south-west of Wagora (21°35′, 78°51′), where the rock seen is a pure limestone, occasionally cherty, but it is difficult to say what the thickness of it may be and whether there is also a gritty band interposed between the limestone and the metamorphics. At three-quarters of a mile south-west of Jakiwara (21°37′, 78°49′) occurs a fine section of the group. The stream, on which Jakiwara stands, flowing over the Lametas has here cut its way back and now exposes the whole thickness of the limestone, coming down in a beautiful waterfall over it. The limestone is a pure light grey rock and thick-bedded, is 15 to 20 feet in thickness and overlies a soft yellowish grey sandstone, composed of coarsish quartz grains with faint lamination in places. The beds have a very slight inclination to north by west. The visible thickness of the sandstone is 4 feet, its actual junction with the metamorphics not being exposed. Northwards from here, the infratrappeans between Sausar (21°40′, 78°51′) and Mohgaon are a white calcareous sandstone, somewhat gritty. At 2½ miles north-east of Sausar, on the Nagpur-Chhindwára Road, the section is as follows:—At the foot of the slope are visible well-foliated thin-banded mica-schists with a foliation-dip of 55° to south-west. On these is found, resting horizontally, a little higher up the slope, a bed, 5 to 8 feet thick, which is a grit at the bottom, but becomes towards the middle portion almost wholly cherty, with patchy enclosures of felspar, quartz, etc., evidently

derived from the underlying metamorphics, while the upper portion of the bed is calcareous and cherty. Overlying this is a thin bed of pure greyish limestone, with a visible thickness of about 5 feet, on which rests the basaltic trap.

Following along the borders of the valley further northwards from here, the infratrappean limestone is met with in most places cropping out from underneath the basalt. Its thickness however is variable, the greatest being 15 to 20 feet, it thinning out to as much as 5 feet or less in some localities, while in some places its place seems entirely taken by a gritty sandstone. Although, thus, in most places some traces or other of the Lametas are observable, there are however some sections where the limestone or its equivalent grit seems absent, either from pre-trap denudation, or on account of original limitation of the Lametas. Such a tract seems to have been about the spur north by west of Kajalwani (21°41′, 78°54′).

Fossils.

Though fresh-water shells such as *Physa* have been mentioned as having been found in the Lametas, none were found in the area under consideration. In one locality only, namely, by the village of Kudum (21°41′, 78°52′) the limestone yielded small casts of shells, but they were too fragmentary and too ill-preserved to admit of identification.

"Trap."

The trap rests in horizontal sheets on the Lametas, the last described group of rocks, and is thus the youngest of all the rocks in this neighbourhood. The trap hills here, as elsewhere, present a characteristic appearance, being flat-topped, like a table, and with more or less steep sides, and covered with scant vegetation.

The rock here is a dark, hard, compact and homogeneous basalt, exhibiting an exfoliating concretionary structure best brought out by weathering. Nowhere however was the columnar structure, so well exhibited in some basaltic flows, met with in the area under question. The rock is amygdaloidal in places, and in these cavities as well as in the joints and cracks in the rock were found beautiful specimens of quartz crystals, agate, calcite, stilbite, etc.

Of the three main classes, *viz.*, Upper, Middle and Lower, into which the Deccan trap has been divided, the trap that occurs in this valley belongs to the Lower division.

Economic Geology.

Stones for building, road-metalling, etc.

Basalt.—Basalt makes a good building material and is also largely used as a road metal.

Quartz and Quartzite.—Another rock that is much used for macadamising roads is quartz. Quartzite is also utilised for similar purposes. Both kinds of rock are plentiful all over the country here.

Calcareous Sandstone.—In localities where the Lametas yield a calcareous sandstone fairly even-grained, it is often used as a building stone for temples, as the rock can be taken out in moderate sized pieces, and dressed easily. The rock however not being compact or homogeneous, cannot be expected to stand much weathering and thus last long.

Crystalline Limestone or Marble.—The crystalline limestone or marble here belongs to the metamorphic series. The rock is often in thick beds and will no doubt receive a good polish in which case it could be well used for building and ornamental purposes. The pink variety would be attractive, especially for ornamental purposes, though however the presence of minute flakes of mica would somewhat detract from its value.

Ordinary Limestone.—There is a fairly large supply of pure ordinary non-crystalline limestone obtainable from the Lameta group of beds. The only use the limestone is put to now is the building of small culverts and bridges and occasionally of temples. Of course where the rock is cherty, sandy or otherwise impure, it could not be commercially valuable, but there is a large quantity of the rock available which is fairly pure and free from impurities, and has, besides, as regards position, the advantage of being easily accessible.

Mineral Ores.

The only metalliferous ore come across in the valley is a manganese-ore. At the time of my visit[1] a little of it[2] was exposed just by the village of Kachi (21°43′ 78°52′), 2 miles south by west of Silora on the Kanhan River, in the district of Chhindwára. The ore which is a mixture of braunite and

[1] Season 1893-94.

[2] Clearings recently made would, according to Mr. L. L. Fermor, who visited the ground during the season 1903-04, seem to show that the mass is at least 50 feet wide. (See page 210 of the foregoing paper.)

psilomelane yielded, as the result of analysis in the Geological Survey Laboratory, the following percentage of constituents :—

Moisture . . .	·26
Manganese . . .	53·25
Phosphorus . . .	·91

Fragments of a similar ore were observed on the ground ¾ mile south-west of Khairi[1] (21°31′, 78°55′), on the Kelod-Sausar Road. Owing to absence of pits or other sections the thickness of the present mass could not be ascertained.

[1] Described by Mr. Fermor as the Gowári Warhona deposit. (See page 214 of the foregoing paper.)

ON MANGANITE FROM THE SANDUR HILLS. BY L. LEIGH FERMOR, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With Plate 22.)

Rarity of Manganite in India.

DESPITE the abundance and importance of the manganese-ore deposits of India, it is a curious fact that though, of the oxide-ores of manganese, pyrolusite, psilomelane and braunite occur in profusion, hausmannite[1] has never been found at all, while manganite has been recorded but twice. One reference to manganite is in the *Records of the Mysore Geological Department*, III, p. 47 (1900 and 1901), where there is a bare mention of this mineral without any details of its locality and characters. The other and prior record is of a specimen received some years ago from the Political Agent at Gwalior, and presumably obtained from that neighbourhood[2]; but, as will be noticed below, though this specimen can be regarded as pyrolusite pseudomorphous after manganite, yet it is certainly not the latter mineral in its fresh condition.

Occurrence of Specimen.

Hence it is that the specimen (J. 877) of manganite, about to be described, is of special interest. It was found by Mr. Charles Aubert at Rámandrug (15° 3′—76° 34′) in the Sandur Hills, Madras Presidency, where the manganese-ores described by Mr. R. B. Foote[3] have been recently found to be sufficiently abundant to pay for working. The ores are said to form an outcrop of huge boulders of psilomelane extending about 450 feet along the strike. A small nodule from this outcrop on being fractured was found to be lined inside with a beautiful growth of needles, and

[1] Mr. R. B. Foote surmises that the manganese-ores he found in the Sandur Hills are either hausmannite or braunite, but the analysis quoted is sufficient to disprove this, as the amount of oxygen found is much in excess of that required for either mineral. *Mem. Geol. Surv. Ind.*, XXV, p. 194, (1895). The specimens he collected are apparently only nodules of very impure psilomelane.

[2] Geology of India, Pt. IV, Mineralogy, by F. R. Mallet, p. 59, (1887).

[3] *Rec. Geol. Surv. Ind.*, XXII, p. 26, (1889); *Mem. Geol. Surv. Ind.*, XXV, pp. 98, 100 and 194, (1895).

Mr. Aubert relates that he incautiously picked up the specimen, and that, as a result, he felt for some time afterwards an unpleasant prickly sensation caused by these needles. Of all the pieces of ore yet fractured, this is the only specimen found to contain this acicular growth of needles.

Description of Specimen.

The specimen, as received, is evidently but a portion (3 in. long by $2\frac{1}{2}$ in. broad) of a geodic nodule, and a natural-size photograph of it is shown in Plate 22; as there was fortunately another smaller portion of this same geode, the mineral could be tested without damaging the main specimen. The walls of the geode are made of compact, very fine-grained, grey psilomelane, sometimes showing a few concentric layers $\frac{1}{5}$ to $\frac{1}{4}$ inch thick with an aggregate thickness of $\frac{1}{4}$ to $\frac{1}{2}$ inch. These layers have sometimes a thin ferruginous staining between them. In one place, the outer side of this shell is smooth, with depressions on it exactly simulating the "thumb marks" on meteorites. The walls of the geode are lined inside with a beautiful bronze-coloured growth of needles having an almost splendent metallic lustre. Where they spring from the walls, they are so close together as to constitute massive manganite, showing however the fibrous structure which soon separates itself into the thick, slightly divergent, growth of needles, which are nearly all approximately at right angles to the shell of the geode. In one place, however, they form divergent tufts, the radiant points of which are close together, and the needles of which consequently cross one another. Over a large portion of the specimen, the needles average $\frac{1}{2}$ inch in length with $\frac{1}{8}$ to $\frac{1}{4}$ inch of the massive mineral below. The thickness of the needles, measured with a stage-micrometer under the microscope averages about 0·02 to 0·03 m.m., ranging from much smaller dimensions up to 0·1 or 0·2 m.m. Hence we see that, on the average, these needles have a length of about 400 times their breadth, so that some idea of their delicacy may be gathered.

Colour.

As already mentioned, this acicular growth shows a most brilliant bronze reflection, which under the microscope is seen to be a metallic pinkish bronze. Such an unusual colour for manganite is probably due to a superficial film of tarnish. As seen from above, the *chevaux-de-frise* of needles has a velvety deep brownish-black appearance showing minute points of light due to reflections from the tiny terminating faces of the needles.

Crystalline Form.

Under the microscope, by reflected light, the needles usually show the faces of a simple prism, probably either *m* (110) or *l* (120), sometimes, however, as is so characteristic of manganite, shewing other bevelling prisms, or even longitudinal striations. These prisms are, as a rule, terminated by a single pair of minute reflecting faces, which suggest the macrodome *u* (101) ; but in some cases there may be four pyramid faces.

Hardness.

To test the hardness was a matter of great difficulty owing to the brittleness of the needles, but by taking a small piece of the specimen and using it as a broom, as it were, and drawing it rapidly across polished surfaces of selenite, calcite and fluor-spar in turn, it was found to scratch gypsum with great ease and calcite less easily, while on the fluorite only two or three very minute scratches could be recognised. Hence this mineral has a hardness about equal to that of fluorite, *i.e.*, = 4.

Streak.

The streak is black with a brown tinge.

Decrepitation Test.

On heating a few needles in a closed tube, a very small amount of water was given off, in fact, much less than would be expected from a mineral containing 10 per cent. of this constituent (the chemical formula of manganite is $Mn_2O_3.H_2O$.) This test was accompanied by violent decrepitation with a splitting of the needles parallel to their length. On applying the same test to a small prism of manganite broken from a specimen from Ilfeld, Germany, this was found, besides yielding water, to decrepitate in the same manner, and under the microscope it was seen that the splitting had taken place along parallel, obviously pinacoidal, planes so as to produce flat parallel-faced laths, and as manganite has a very perfect cleavage parallel to the brachypinacoid *b* (010), this is doubtless the direction of parting under the influence of heat. This decrepitation test is hence probably a very useful one for this mineral.

Pseudomorphism to Pyrolusite and Psilomelane.

It will be seen that, considering all the above evidence, there is no doubt that this mineral is manganite; the small amount of water given off on heating and the nearly black streak may be ascribed to an incipient change towards pyrolusite, a mineral which has been frequently observed to form pseudomorphs after manganite. This very specimen, in fact, shows manganite completely changed in one place (A in the photograph) to soft bluish-black pyrolusite still

retaining more or less of the acicular structure of the manganite. This pyrolusite gives place, right in the corner of the specimen where the roof and floor of the geode meet to form an angle (at B at the back of the specimen as shown in the photograph), to a massive, bright, steel-gray mineral not scratched by a knife. This mineral is probably psilomelane, but, nevertheless, still preserves in itself radiating lines, the hall-mark, in fact, of the manganite, after which it is doubtless pseudomorphous.

Pyrolusite Pseudomorph from Sitapar.

At Sitapár (21°44½′—78°54½′) in the Chhindwára district, I have myself collected specimens (17·10), composed of a complex of manganese-ores and other minerals, showing amongst them prisms which have the outward crystalline shape of manganite, but which are scratched with great ease by a knife and yield a black powder, so that they must be regarded as pyrolusite. This is doubtless another case of pyrolusite pseudomorphous after manganite.

The Gwalior Specimen.

The above-mentioned (page 229) Gwalior specimen (G.933) consists largely of more or less parallel layers, averaging ⅛ inch thick, of a black mineral with a sort of parallel, sometimes platey and sometimes prismatic, structure roughly at right angles to the layers, and with the colour, lustre, streak and hardness of pyrolusite. Besides a coating of botryoidal psilomelane in one place, there is some red clay between these "manganite" layers. Though it yields a little water in the closed tube, yet the prismatic chips do not decrepitate and split. Hence this mineral is probably pyrolusite, no doubt possibly pseudomorphous after manganite. In a little cavity, indeed, are some tiny lustrous black intersecting plates, with parallel striations, which, if the mineral be considered to be manganite, may be regarded as an extreme development of the flattened form of this mineral shown in Fig. 1, page 248, of Dana's "System of Mineralogy" (1892).

MISCELLANEOUS NOTES.

Note on the Occurrence of Gypsum in the Vindhyan Series at Satna.

AS far as I can discover from the publications of the Geological Survey of India gypsum has never been recorded from the ancient group of unfossiliferous rocks known to Indian geologists as the Vindhyan System. Considerable interest, therefore, attaches to some core-samples (19·217) sent by Messrs. Gladstone, Wyllie & Co. of Calcutta. They were extracted during the sinking of a bore-hole for water into the Vindhyan rocks at Satna, Bághelkhand, Central India, and come from depths of 200 to 338 feet. The bore-hole traverses the Sirbu Shales, the uppermost division of the Lower Bhander, and the pieces of core received consist of green, red and purple shales with some interbedded grey sandstone. Several of the core segments show layers of fibrous gypsum, varying between $\frac{1}{4}$ and $\frac{5}{8}$ inch in thickness and arranged parallel to the bedding of the shale which, as far as can be judged from the cores, is roughly horizontal. In one case the gypsum layer is seen to thin out in lenticular fashion. Where the gypsum occurs in the sandstone it is either as irregular patches or as impregnations. One section of core $5\frac{5}{8}$ inch long is mainly gypsum with shale partings ; the gypsum in this segment is partly in fibrous layers and partly irregularly crystallized so as to include fine sand grains.

It is evident that throughout the thickness of 118 feet (200 to 318 feet) through which the gypsum is found, there occur at intervals in the shale thin fibrous layers of gypsum which certainly sometimes, and probably always, tail out in lenticular fashion.

The question now arises as to how the gypsum reached its present position, *i.e.*, whether it was deposited contemporaneously with the associated shales and sandstones or whether it has been introduced subsequent to their deposition. One of the core-segments was broken up and tested for sodium chloride by boiling with distilled water, filtering and adding silver nitrate. The slight opalescence produced was less than that given by an equal volume of Calcutta tap water, so that sodium chloride can be considered as absent from the gypsum.

Taking into account both the absence of sodium chloride and the thinness of the gypsum layers it is difficult to imagine that the gypsum was formed by the drying up of saliferous pools or lakes at intervals during the deposition of the shales. In one piece of core some sharply bounded isolated pieces of

shale are included in the gypsum and this points to the second hypothesis, namely :—that the gypsum is a subsequent introduction. In fact we may suppose that gypsiferous waters found their way along the bedding planes of the Sirbu Shales and there deposited their contents. The included shale fragments possibly indicate that the deposition, at least in part, took the form of metasomatic replacement of the shale by gypsum; it may also have been in part deposited in places where the rocks opened up slightly along the bedding planes during the earth-movements which have slightly tilted the Vindhyans of this area. When the gypsiferous waters reached a porous sandstone layer, then they deposited their gypsum between the sand grains.

[L. L. FERMOR.]

Ores of Antimony, Copper and Lead from the Northern Shan States.

In 1905 four specimens of metalliferous ores from the Northern Shan States were forwarded to the Geological Survey Office by the Revenue Secretary to the Government of Burma.

The most interesting of these was a sample (J. 766) of *stibnite* largely converted into *cervantite;* it was obtained from Lat. 22°28′ N. and Long. 96°34′ E., Hsumhsai Sub-state, Ye-U Circle.

Although it has long been known that ores of copper and lead occur in the Shan States, yet the remaining three samples are worth mentioning as we know their mineral composition and exact localities. They are :—

(1) Pieces of grey schistose slate and vein quartz with sparsely scattered *chalcopyrite*, abundant films of *chrysocolla*, and some *malachite;* from near Letpandaw village (22°30′—96°25′), Mong-Lung Sub-state, Kainggyi Circle (J. 765).

(2) *Galena* with crusts of *cerussite* and containing in places a little quartz; from about 4 miles west of Namsaw (22°31′—96°51′), Hsipaw State (J. 764).

(3) *Galena* scattered through finely crystalline grey limestone, from Man Paw (22°5′—97°55′), 12 miles east of Möng Tung village, Möng Tung Sub-state (J. 767).

[L. L. FERMOR.]

Gems from the Tinnevelli district, Madras.

A parcel of 420 "precious stones" picked up by villagers in the gravelly tracts of the village of Mel Amathur (9°31′—77°52′), Satür taluq, Tinnevelli

district, was received from Mr. G. H. B. Jackson, Divisional Officer, Satur. It seems that on the discovery of these supposed precious stones the villagers, having an exaggerated idea of their value, assembled in numbers to collect them and thus called the attention of the local officials to the find.

A large proportion of the stones received consist of angular (probably freshly broken) and waterworn fragments of garnet (J. 971—J. 973), some as large as ⅝ inch across. They vary in colour from pink and brownish-pink to a beautiful deep red and are often sufficiently clear and free from flaws to be used as cheap gems.

The small proportion of stones that are not garnet include 5 very deep green (almost black) spinels probably pleonaste (J. 974), one black tourmaline, and one piece of titaniferous magnetite. There was also one small black pebble, ½ inch in diameter, which shows resemblance to both sapphirine and serendibite, but is not exactly the same as either. It is black in colour, but small chips are transparent showing the following striking pleochroism :—

Direction of greater elasticity=rich bluish green.

Direction of lesser elasticity=pale greenish to greenish yellow.

The mineral is biaxial, with an optic axial angle similar to that of muscovite. No cleavage, but conchoidal fracture. Vitreous lustre. H.=7. G.=3·367 B. B. infusible, but changes colour to greenish or greenish white. With borax and microcosmic beads gives a faint colour for iron.

[L. L. FERMOR.]

Cassiterite-granulite from the Hazaribagh district, Bengal.

A specimen (J. 862) recently obtained by Mr. C. Jambon of Calcutta from Chappatand (24°41′—86° 0′), Házáribágh district, was found on examination to be a cassiterite-granulite in which the cassiterite or tin-stone formed perhaps ⅓ to ½ of the rock. The other constituents of the rock are magnetite, quartz, oligoclase, a little orthoclase, a small quantity of a rich green hornblende and a still smaller amount of biotite. The minerals are all more or less equi-dimensional and associated in a granulitic manner. The cassiterite under the microscope is pale brown to pale pinkish and often shows rich brown spots and sometimes also central zones of the same colour disposed parallel to the vertical axis. Other portions of the mineral have all but the periphery densely crowded with minute rod-like (or plate-like) indeterminate inclusions which are often so numerous as almost to make the mineral opaque, the colour then becoming hair-brown. They are definitely arranged in two parallel sets, one of them parallel to the faces of a pyramid [probably *s* (111)], and the other parallel to the vertical axis. The cassiterite

often shows thin hemitrope bands or lines due probably to twinning on *e* (101). In places the rock becomes practically a cassiterite-rock to the exclusion of all the other minerals; the cassiterite individuals are then occasionally seen to interlock almost graphically.

Although this is a new locality for cassiterite in India, yet it is only about 11 miles E. N. E. of Simratari where Mr. Mallet found "a few crystals of tin-stone in a lenticular pocket of granite in mica schist."[1]

Tin-ore is already known at Nurunga (24°10′—86°8′)—also in the Házáribágh district—where the ore is described by Mallet [2] as occurring "in three or four lenticular beds or nests in the gneiss."

A microscopic examination of this ore showed that it also is a cassiterite-granulite which is almost indistinguishable both macroscopically and microscopically from the Chappatand rock. Some of the pieces of rock are, like the Chappatand specimen, more or less homogeneous as regards the distribution of the constituent minerals; but other pieces have a streaky or patchy arrangement of the dark and light minerals, thus imparting a gneissose appearance to the rock. The only difference to be noticed microscopically consists in the presence of some microcline and a fair abundance of orthoclase.

There can be no doubt that the cassiterite-granulites of these two localities are genetically one rock, and the occurrence of the tin-stone in such a rock as a granulite, which often occurs as bed-like masses intercalated between the other bands of a parallel-structured complex of metamorphic and igneous rocks, would almost encourage the hope of finding large quantities of this valuable ore of tin. When traced to its parent rock, cassiterite is almost invariably found as a constituent of granite or pegmatite, or of fissure-veins and stock-works associated with such acid igneous rocks as granite, pegmatite and quartz-porphyry. Such a mode of occurrence of tin-stone as that described in this note seems to be unique; it has, however, some similarity as regards mineralogical association to that of the tin-stone recently found by Mr. C. T. Clough[3], in what are believed to be basic segregations, in the granite gneiss of Carn Chuinneag, Ross-shire, Scotland. These supposed segregations consist chiefly of magnetite and contain small quantities of cassiterite (*nil* to 17°/₀) as well as quartz, orthoclase, plagioclase, muscovite, biotite and rutile; these latter are, however, so disposed as to give the mass a foliated structure not possessed by the Indian cassiterite-granulite.

[1] Manual of Geology of India, III, p. 315, (1881).

[2] *loc., cit.*, p. 314; *Rec, G. S. I.*, VII, p. 35.

[3] Summary of Progress of the Geological Survey of the United Kingdom for 1903, pp. 58, 59.

[L. L. FERMOR.]

Imports and Exports of Mineral Products during 1905.

The following extracts from the returns published by the Director-General of Commercial Intelligence will be of interest to those engaged in the mineral industries, and may be compared with those published last year (*Rec. Geol. Surv. Ind.*, XXXII, part 2, p. 185). The table of values given below shows the values of imported mineral products, exclusive of articles like hardware, cutlery, plated ware, machinery, mill-work, railway plant, glass and earthenware, most of which have values much in excess of those of the metals and minerals of which they are composed.

Imports.

Value of Imports of Mineral Products for the years 1902—1905
(including Government Stores.)

	1902.	1903.	1904.	1905.
	£	£	£	£
Salt	458,251	408,941	471,096	422,803
Metals: Brass	90,449	71,094	69,946	71,800
Copper	1,258,548	1,327,172	1,751,744	1,173,110
German Silver	139,955	98,605	127,563	113,771
Iron	2,088,777	2,396,053	2,808,915	2,289,535
Steel	1,396,634	1,740,752	1,799,173	2,098,692
Lead	127,504	124,392	129,315	151,248
Quicksilver	27,562	30,648	27,472	23,284
Tin	177,138	227,140	263,194	188,913
Zinc or spelter	87,986	96,588	110,891	93,446
Unenumerated	86,521	77,135	81,244	140,646
Inorganic Chemicals	375,933	379,403	395,018	465,375
Mineral Oils	2,231,946	2,302,865	2,230,755	1,765,151
Coal, Coke and Patent Fuel	336,420	238,428	325,613	252,495
Precious Stones and Pearls, unset	843,520	987,618	589,679	853,256
Stone and Marble	18,789	22,598	17,877	27,714
Other Building Materials	158,360	176,213	226,428	295,599
TOTAL	**9,904,293**	**10,705,645**	**11,425,963**	**10,426,838**

The most interesting feature in connection with the import statistics is shown by the returns for mineral oil: on account of the increased output of Burma oil, there has been a continuation of the decline in the total, from 79,301,774 gallons in 1904 to 71,792,867 gallons in 1905, and there has also been a thorough re-arrangement amongst the suppliers. On account of the disturbances in the Baku region, Russia, instead of being, as heretofore, the main source of the kerosene imported into India, fell behind both the United States and the Dutch East Indies. The figures for the last three years are as follows:—

Imports of Kerosene during the years 1903—1905.

	1903.	1904.	1905.
	Gallons.	Gallons.	Gallons.
Russia	65,434,324	42,256,738	17,060,719
United States	7,588,569	7,628,275	18,738,137
Dutch East Indies	3,334,207	19,483,448	26,512,393
Other Countries	4,479	1,222,397	16,379
Total	**76,361,579**	**70,590,858**	**62,327,628**

Exports.

Until recently the export trade in chromite, graphite and magnesite has been small, and returns for these minerals have not been shown separately in trade summaries. With a continuation of present developments it will be possible soon to split off certain of the larger constituents from "unenumerated" and "other" groups.

Borax and Saltpetre.

There was again a slight decline in the export of borax from 4,246 cwt. valued at £5,419 in 1904 to 4,198 cwt. valued at £5,246 in 1905. The saltpetre sent to Europe and the United States also declined seriously, being only partially balanced by an increased export to China. The total quantity exported during 1905 was 313,122 cwts., valued at £235,723, against 390,970 cwt., valued at £266,349 in 1904.

Coal.

From the point of view of the Indian producer, the outward and inward trade in coal both improved. The imports declined from 253,874 tons in 1904 to 197,784 tons in 1905, whilst the exports increased from 602,810 tons, which was up to 1904 the highest record, to 783,760 tons. The increase in export was largely due to the replacement of Japanese by Indian coal in the Singapore market.

Jadestone.

There has been no serious change in the returns for jadestone; but the figures included in the sea-borne trade represent only a part of the total trade, much of the material being sent overland from Upper Burma into China. The quantity of jadestone exported through Rangoon in 1905 was valued at £43,474, against a value of £43,946 in 1904.

Manganese-ore.

The most striking change in connection with the export figures is that due to the great increase in manganese-ore. There was a considerable rise in prices during the year due to a partial failure in the Russian supplies following the internal disturbances in the country. Russia has been hitherto the source of nearly half the world's supply of manganese-ore, and the recent disturbances there have specially benefitted the Indian and Brazilian mine-owners. From India during 1905 the manganese-ore exported amounted to 281,735 tons, against 154,829 tons in 1904. The declared values do not give a correct idea of the prices realized, which must have been much higher during the latter half of 1905 than in 1904. At the commencement of 1905 the unit price at European and American ports for high-grade ores was under 9*d.*, but prices increased about June and July, and exceeded one shilling per unit before the end of the year.

Mica.

There has been a very satisfactory development of the export trade in mica, largely due to a great increase in the output of the flimsy mica used for the manufacture of micanite. The total amount sent out of India in 1905 was 133,159 cwt., valued at £142,008, against 18,250 cwt., valued at £83,183 in 1904: the increase in weight was thus greatly in excess of the increase in value.

Petroleum.

By an arrangement between the companies working oil in the Dutch East Indies, and those in Burma, the latter have relinquished certain Eastern markets, but have found a market for their increased production in India. Thus the export of mineral oil has declined from 3,787,677 gallons valued at £120 537 in 1904 to 2,422,589 gallons, valued at £80,945 in 1905. The effect of the increased output of oil in Burma, and its use there and in India, is shown by the figures for the imports of foreign oil already referred to. There has been a considerable increase in the production of paraffin wax, the exports having developed as well as the home consumption. In 1905 the paraffin-wax exported amounted to 63,966 cwt., valued at £86,637, against 42,940 cwt., valued at £58,018 in 1904.

[T. H. HOLLAND.]

G. I. C. P. O.—No. 4 D. G. Survey—3-5-06—700.

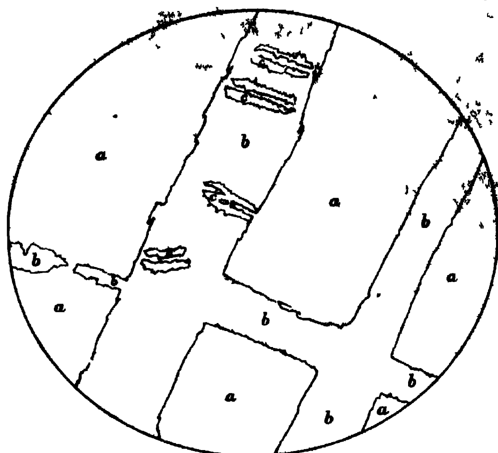


Fig. 1—17·68— × 38 (See p. 174)

(a) **The bands are the original parting planes of the pyroxene preserved in silica.**
(b) **Veins of very fine-grained quartz in which the original structure is obliterated except for the fragmentary remains *(c) (c)***

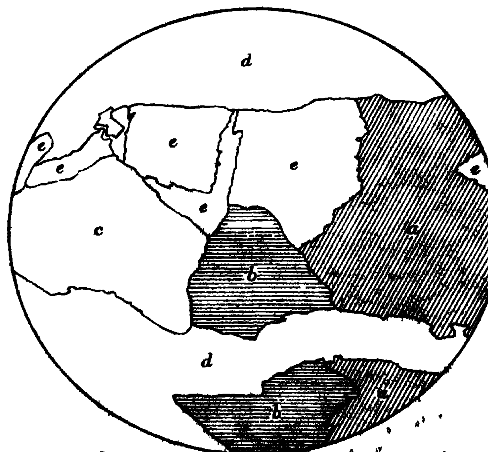


Fig. 2—17·74—Nicols [illegible]

(a) **Parts of one original** [illegible]
(b) [illegible] **felspar** [illegible]
(c) **Original felspar.**
(d) **Secondary, very** [illegible]
(e) **Other original** [illegible]

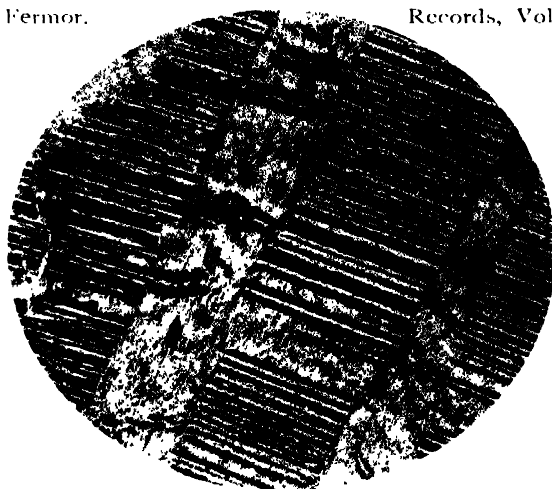


Fig 1



Fig. 2

L. L. Fermor, Photomicrograph. *Bemrose & Sons Limited Derby*

L. L. Fermor

(Explanatory skeleton)

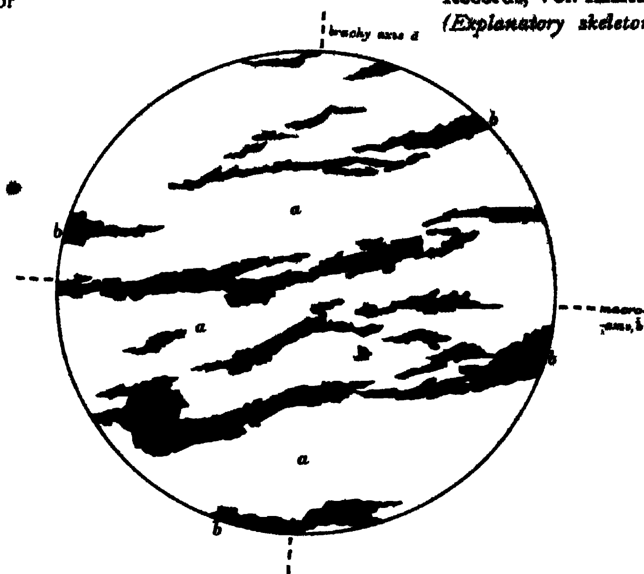


Fig. 1—17 58—Nicols crossed— × 38 (See p. 177)

Section is parallel to the basal plane of the microcline (a) showing perthite bands (black) making an angle of roughly 10° with the macro-axis of the microcline. The perthite is twinned parallel to (b)

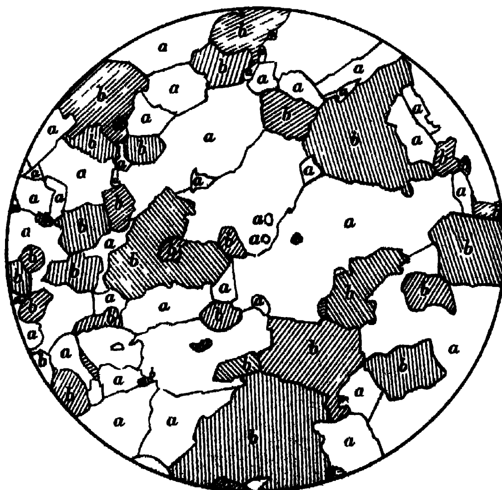


Fig. 2—17 44—Nicols crossed— × 27 (See p. 179)

(a) Microcline.

(b) Quartz (shaded).



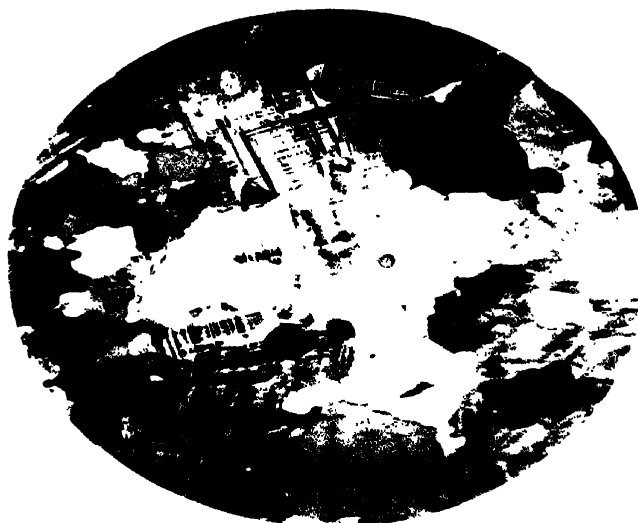


Fig. 2

L. Fermor, Photomicrograph

L. L. Fermor.

Records, Vol. XXXIII, Pl 16

(Explanatory skeleton)

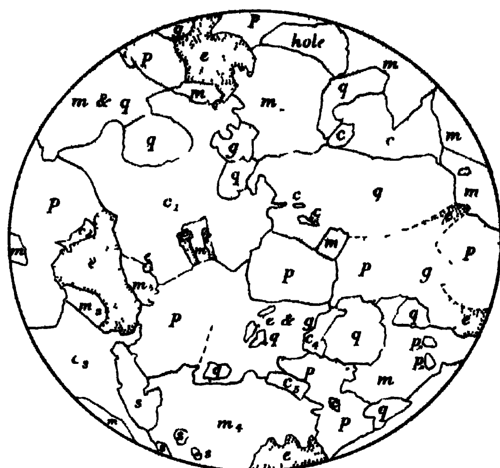


Fig 1—16 937— × 38 (See p 190)

(c) Calcite
(e) Epidote
(g) Garnet
(m) Microcline
(p) Pyroxene
(q) Quartz
(s) Sphene

m & m_2 extinguish together
m_3 m_4 & m_5 do
c_1 c_2 & c_3 do
c_4 & c_5 do

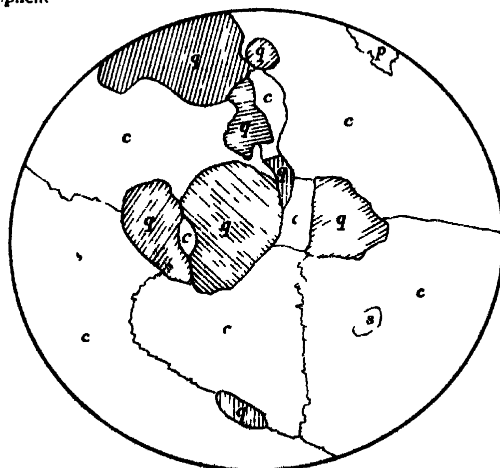


Fig 2—16 940—Nicols crossed — × 38 (See p. 198)

(c) Calcite.
(q) Quartz (shaded).
(s) Sphene.
(p) Pyroxene.



Fig

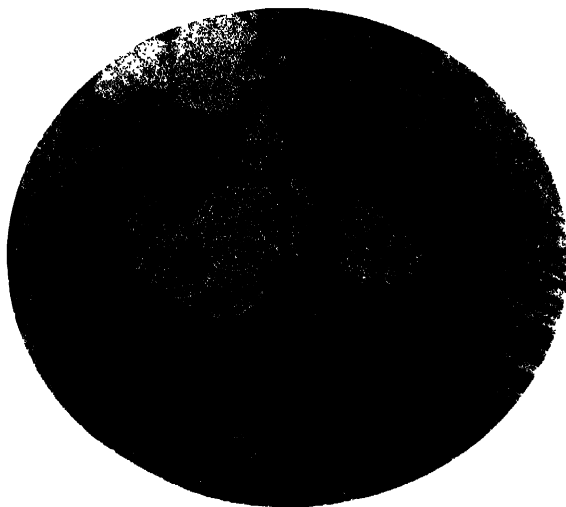


Fig. 2

L. L. Fermor, Photomicrograph.

Bemrose & Sons Limited, Derby.

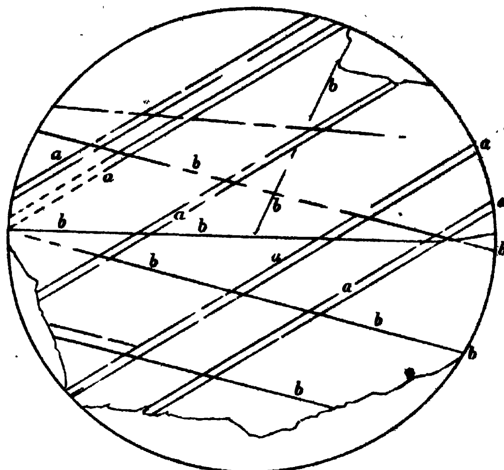


Fig. 1—16·964—Nicols crossed— × 38 (See p. 201)

Calcite showing twinning planes *(a)* and cleavage planes *(b)* both marked out b manganese-ore dust. Where *(a)* shows white there is no manganese-ore.

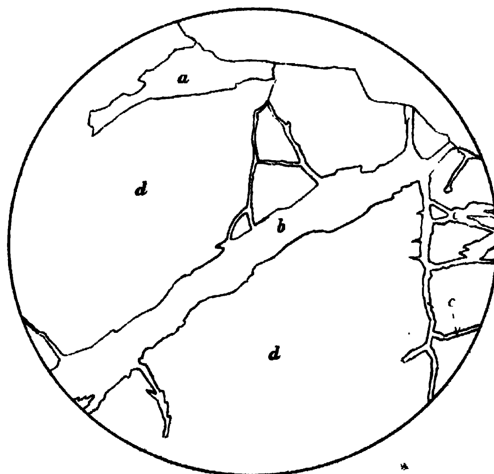


Fig. 2—16·952— × 38 (See p. 202)

(a) Amphibole.

(b) Vein of calcite with serpentine along edges.

(c) Veinlets some entirely serpentine and some with a central band of calcite.

(d) Pyroxene very much veined by thin serpentine strings and with little patches of colourless amphibole in places.



Fig. 1



Fig. 2

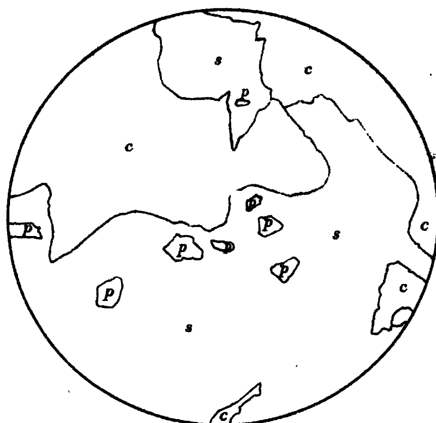


Fig. 1—16·951—Nicols crossed— × 68 (See p. 202)

(c) Calcite.
(p) Pyroxene.
(s) Serpentine.

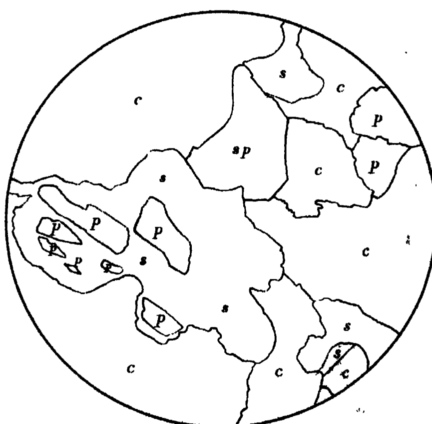


Fig. 2—16·954—Nicols crossed— × 38 (See p. 204)

(c) Calcite. *(s)* Serpentine.
(p) Pyroxene. *(sp)* Spinel.



Fig. 1



Fig. 2

L. L. Fermor Ph[illegible]ograph

L. Fermor

Records, Vol XXXIII, Pl. 19
(Explanatory skeleton)

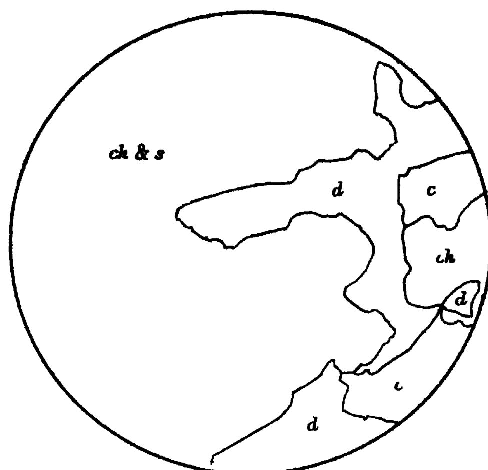


Fig 1—16 958—Nicols crossed 38 (See p 20?)

(c) Calcite
(ch) & *(s)* Chondrodite *(ch)* veined with serpentine *(s)*
(ch) Chondrodite
(d) Dolomite

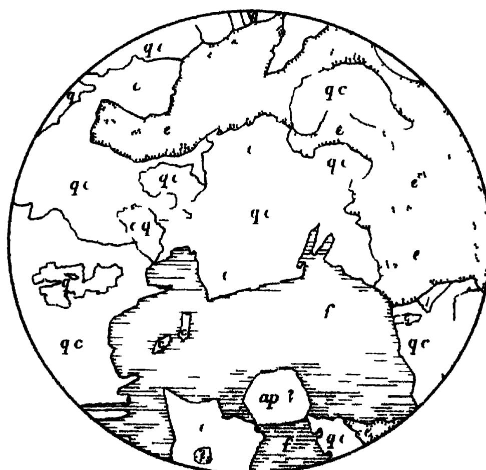


Fig 2 16 946—Nicols crossed 66 (See p ?0?)

(ap) Apatite
(c) Calcite
(e) Epidote (stippled)
(f) Felspar (shaded)
(q) Quartz
(q c) & *(c q)* Quartz-calcite, & calcite quartz micropegmatite.

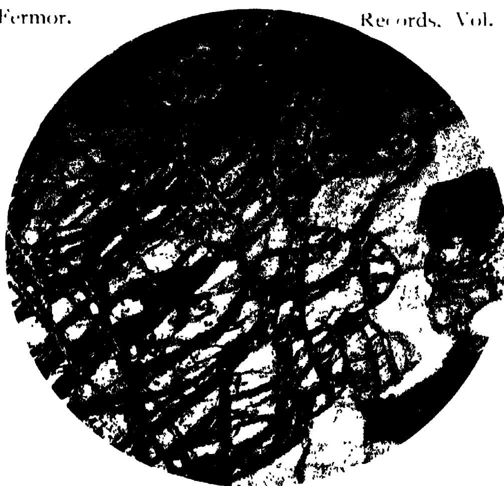


Fig. 1



Fig. 2

L. L. Fermor, Photomicrograph.

GEOLOGICAL MAP

OF A PORTION OF

THE KANHAN RIVER VALLEY, CHHINDWARA AND NAGPUR DISTRICTS, C. P.

Scale 1" = 4 Miles.

INDEX.

Deccan Trap

Lametas

Metamorphics

Dips



L. L. Fermor. Records, Vol. XXXIII, Pl. 22



H. B. W. Garrick, Photo.

A PSILOMELANE GEODE LINED WITH MANGANITE NEEDLES

(A). PYROLUSITE PSEUDOMORPHOUS AFTER MANGANITE

(B). (*[illegible] specimen*) PSILOMELANE PSEUDOMORPHOUS AFTER MANGANITE

Natural Size.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] **1906.** **[June.**

SUPPLEMENTARY REPORT ON THE COMPOSITION AND QUALITY OF A SERIES OF INDIAN COALS. BY PROFESSOR WYNDHAM R. DUNSTAN, M.A., LL D., *Director of the Imperial Institute.*

Origin of the Report.

IN 1903 the Director of the Geological Survey of India suggested that as it was proposed to make a re-survey of the Bengal coalfields in a short time it would be useful if the preliminary examination of these coals already made at the Imperial Institute could be supplemented by determinations of the amount of moisture and of phosphorus contained in them, the former constant being of special interest in relation to the geological age of the coal, and the latter with reference to its suitability for iron-smelting.

In compliance with this suggestion, the quantities of phosphorus and moisture have been determined for the whole series of Indian coals previously examined, the lump samples which were prepared at that time and have since been preserved in air-tight tins, being employed for this purpose.

The results of this work are given in the appended tables which, as a matter of convenience, show the additional results interpolated in a printed set of the tables which accompanied the former report (Indian Agricultural Ledger No. 14, 1898; also "The Coal Resources of India and their Development" by Professor Dunstan, Technical Reports and Scientific Papers, Imperial Institute, 1903).

In the same way the analytical methods by which the additional results have been obtained are included in the general statement of methods of examination which was given in the previous report. In this form it is considered that the present report will be more convenient for reference.

It will be seen that whilst many Indian coals contain very small amounts of phosphorus, others contain a sufficient amount to take into consideration if it were intended to employ them for the manufacture of coke to be used for iron-smelting. In these cases the amounts of phosphorus contained in the finished cokes should be determined before deciding on the suitability or otherwise of these coals for the purpose.

Constituents determined.

The constituents which have been determined are : *fixed carbon*, perhaps the most significant datum not only in reference to the value of the coal as such, but also as affecting the quality of the coke (*i.e.*, fixed carbon and ash) obtainable from it; *ash* or *mineral matter*, a high percentage of which is characteristic of an inferior coal; volatile matter, including bituminous constituents, *gas*, *moisture* and finally *sulphur* and *phosphorus*, large proportions of which are objectionable for most of the purposes for which coal is employed, and especially for the smelting of iron.

In addition to the foregoing an approximate determination has been made of the heat-producing power of the principal coals by ascertaining their thermal value or calorific equivalent. The general characters and caking quality of each coal have also been recorded.

Method of sampling and analysis.

For purposes of reference the following particulars of the methods employed are given :—

Sampling.—Pieces of several pounds weight were sawn from the large blocks, weighing from ½ to 1 cwt. in most cases, which formed the specimens, and these were completely broken up and averaged. The specimens generally, as received, were stated to be fairly representative of the seams from which they were taken.

Technical analysis.—The percentages of fixed carbon, moisture, volatile matter, sulphur, phosphorus and ash were determined under the following conditions :—

About 0·2 gram of the finely-powdered coal was weighed out into a tared platinum crucible; the latter was supported twelve inches above the working bench, and heated over a No. 8 Fletcher-Bunsen burner, working at full power for two minutes ; it was then immediately subjected to a blow-pipe flame for two minutes longer, being kept at a bright red heat. After cooling in a desiccator it was weighed and the loss reckoned as volatile matter, which, of course, included moisture.

(These results were quoted in the previous report as "volatile matter." In the present report the "volatile matter" in this number is corrected by the subtraction of the "moisture" determined, as subsequently described.) The well-fitting lid of the crucible was not removed during the whole of this process. In the case of caking coals a very small quantity of soot sometimes remained on the under side of the lid and escaped combustion. These determinations were made in duplicate and passed if the difference was not more than 0·3 to 0·4 per cent. at this stage. The crucible was then put into a muffle furnace with the lid half off, and heated till nothing but ash remained, when it was cooled in the desiccator and weighed. The loss was reckoned as fixed carbon, and the residue as ash; the colour of the ash will be found recorded in the tables.

Sulphur.

For the estimation of the sulphur about 1·5 grams of coal were fused in a platinum dish with thirty grams of the following fusion mixture:—sodium chloride, 4 parts, potassium nitrate, 3 parts, sodium carbonate (dry), 1 part. The mixture was slowly heated, and, after a short time, it deflagrated and became liquid; when cool it solidified into a white cake, which was dissolved in boiling water; the solution was filtered, acidified with hydrochloric acid, and while quite hot, precipitated with barium chloride. By keeping the beaker and its contents warm on the water bath for three or four hours, the precipitate of barium sulphate was obtained in a granular form very suitable for filtering. Most of the filtering was done through a felt of asbestos placed in the bottom of the perforated platinum crucible, with the help of a water pump, this being a modification of Gooch's method. Careful test experiments showed that in point of accuracy this method was at least equal to that ordinarily used, *viz.*, igniting the precipitate of barium sulphate in a crucible; it is for speed much to be preferred. These estimations were made in duplicate, a difference of 0·3 per cent. being considered quite allowable after considerable experience. In some cases the sulphur left in the coke was estimated.

Phosphorus.

For the estimation of phosphorus five grams of the sample were incinerated in a platinum dish. The ash obtained was boiled for about one hour with strong hydrochloric acid and the soluble portion filtered off. The phosphoric acid was then precipitated along with ferric and aluminium hydroxides, by means of a solution of ammonia, and separated from

the latter by dissolving the precipitate in nitric acid and adding a solution of ammonium molybdate. The precipitate of ammonium-phospho-molybdate was then dissolved in a solution of ammonia and to the liquid "magnesia mixture" was added. The precipitate was allowed to stand over night, filtered and finally weighed as magnesium pyrophosphate ($Mg_2 P_2 O_7$).

In cases where the amount of ammonium-phospho-molybdate was small the precipitate after solution in ammonia was filtered into a tared platinum dish and the solution evaporated. The residue after gentle ignition was weighed, and the percentage of phosphorus obtained by multiplying the weight of the residue by the factor 0·0163.

Ultimate analysis.

The ultimate analysis was conducted in the usual manner. The coals were first dried in a current of hydrogen gas at 120°C. for half an hour, and the resulting loss in weight taken as the moisture; this was done by pushing the platinum boat containing the weighed quantity of coal into the centre of a long piece of hard glass tubing, which itself was passed through the walls of a hot air bath. Hydrogen was led in at one end and allowed to diffuse through a small piece of fine tubing packed with cotton wool, inserted in a cork at the other end. A burner was lighted under the air bath which was provided with a thermometer. The coal, after being dried, was then burned in the usual way in a piece of hard glass tubing. The tube used was filled to a length of fifteen inches with copper oxide (from wire), and to the extent of four and a half inches with lead chromate, these materials being kept in position by plugs of fine copper gauze. The total length of the tube was about thirty-four inches. It will be noticed that the amount of ash, as determined in the combustion, was in some cases distinctly higher than when estimated by the technical method. This is doubtless due to the presence of iron and other mineral substances in the ash, which are left in a higher state of oxidation after being heated in oxygen.

Calorific value.

The calorific equivalent has been determined by means of Thompson's calorimeter, the apparatus being previously standardised by the combustion of material of known calorific value and the necessary correction applied to the experimental numbers. The results are stated in calories. The "evaporative power" was calculated by dividing the calorific equivalent by the latent heat of evaporation of water (537), and

represents the number of units of water at 100°C. which would be converted into steam at the same temperature by the combustion of a unit mass of coal.

Relations of stratigraphical position and moisture.

The arrangement of analyses according to decreasing percentages of moisture, suggested by the Director, Geological Survey of India, has been carried out for all the coalfields in order to make the statement of results uniform. The analytical results of coals from the Raniganj field show, as regards the amcunt of moisture, a gradual passage from the Raniganj stage to the Barakar stage of the Damuda series. From these results alone it would be impossible to classify those at the bottom of the Raniganj series with any certainty. The smallest moisture in the Raniganj series is No. 1668 "Sanctoria" with 3·25 per cent. The greatest moisture of the Barakar series is No. 7746 "Petana" with 2·45 per cent. There is therefore a much greater divergence between coals of the Raniganj series than between the lowest of the Raniganj series and those of the Barakars. The percentage of moisture is also to some extent indicative of the stratigraphical order in the Raniganj series, coals showing the larger percentage of moisture generally belonging to the higher seams in the Raniganj series, but the upper and lower seams cannot be separated absolutely in this way.

The analytical work involved in connection with this re-statement of the results has been carried out under my direction by Mr. G. S. Blake, A.R.S.M., in the Scientific and Technical Department of the Imperial Institute.

WYNDHAM R. DUNSTAN.

28th February, 1906.

Results of Ultimate Analyses of selected Indian Coals.

Indian invoice number.	Imperial Institute number.	PROVINCE AND MINE.	Carbon per cent.	Hydrogen per cent.	Ash per cent.	Moisture per cent.	Phosphoric acid per cent.	Sulphur per cent.	Nitrogen, oxygen, etc., per cent.
		Assam.							
1828	3032	Makum	77·31	5·43	1·26	3·07	0·01	1·02	11·90
95	1445	Cherrapunji	77·75	5·83	4·73	1·45	0·01	3·98	6·25
97	1446	Maoflong	75·05	5·17	3·22	3·15	0·01	3·08	10·32
		Baluchistan.							
93	1441	Khost	71·38	4·97	5·56	3·85	0·01	4·82	9·41
94	1442	Do.	70·58	5·55	10·61	2·46	0·03	0·74	10·03
		Bengal.							
99	...	Kumardubhi	70·43	4·70	13·79	1·86	0·05	0·53	8·63
639	1983	Karharbari Lower Seam . . .	80·75	4·32	7·34	1·23	0·03	0·42	5·91
641	1985	Do. Upper Seam . . .	83·53	4·59	5·26	1·28	0·09	0·40	4·85
1658	2862	Sodepore	72·09	4·87	8·91	3·54	0·09	0·29	10·18
1659	2863	Laikdih	75·33	4·60	9·21	2·23	0·08	0·53	8·02
		Burma.							
3531	6157	Letkohbin	60·25	4·64	9·26	11·55	0·02	0·33	13·95
		Central Provinces.							
1651	2855	Mohpani	67·65	4·37	9·71	7·07	0·02	0·43	10·75

Tabulated Results of Examination of Indian Coals.

Indian invoice number.	Imperial Institute number.	Date.	Mine.	Whence Received.	Remarks made in forwarding sample.	Evaporative power.	Calorific value.	Fixed carbon per cent.	Ash per cent.	Coke per cent.	Volatile matter per cent.	Moisture per cent.	Phosphorus per cent.	Sulphur per cent.	Caking properties.	Colour of ash.	Other characteristics of the coal.
								A.—TERTIARY COALS.									
								Assam.									
*8293	7778	2nd Nov. 1896	Dikhu Valley	Dikhu Valley, Nazira, Assam.	...	11·22	6,028	51·40	2·35	53·75	40·42	5·83	0·000	3·45	Does not cake	Dark reddish brown.	A very bright coal, black as pitch and of conchoidal fracture; intersected with dull layers.
*97	1446	4th Oct. 1894	Maoflong	Maoflong Coalfield	......	13·27	7,128	49·79	2·95	52·75	44·10	3·15	0·001	3·08	Cakes	Yellowish brown	Bright and clean with fossil resin in many places.
*1828	3032	Do.	Makum	Assam Railways and Trading Company (Ledo Valley).	.	12·76	6,853	53·28	1·27	54·55	42·38	3·07	0·001	1·02	Does not cake	Pale chocolate	A glistening black coal, clean to handle, easily broken, conchoidal fracture.
6953	7082	11th Jan. 1896	Do.	Assam Railways and Trading Company, Limited.	2 cwt. Makum coal	13·42	7,205	47·84	3·66	51·50	46·00	2·50	0·008	4·87	Cakes	Reddish brown	Very dirty and dusty coal, breaks readily with irregular fracture, alternately dull and bright.
*96	1445	4th Oct. 1894	Cherrapunji	Cherrapunji Coalfield	......	14·34	7,702	49·54	4·74	54·28	44·27	1·45	0·001	3·98	Do.	Dark red	A dull black coal, dirty, very hard, with cuboidal fracture.
								Baluchistan.									
*93	1441	Do.	Khost Colliery	Khost Colliery, Khost Seam.	...	12·35	6,633	49·58	5·15	54·73	41·42	3·85	0·010	4·82	Do.	Terracotta	Clean, bright and hard, but disintegrating with a white efflorescence and with evolution of sulphuretted hydrogen.
94	1442	Do.	Do.	Khost Colliery, Killa Hakim Seam.	......	12·92	6,936	41·50	9·56	51·06	46·48	2·46	0·017	0·74	Do.	Yellowish brown	Clean, bright and hard, with obtuse fracture.
								Burma.									
*3531	6157	4th Oct. 1894	Letkohbin	Burma Coal Company, Limited.	From roof of seam	—	—	33·57	8·50	42·07	47·08	10·85	0·007	0·33	Does not cake	White	Dull black, clean and hard, with rounded surfaces and fracture.
*3532	6158	Do.	Do.	Do. do.	From floor of seam	—	—	3·56	68·39	...	23·37	4·68	0·012	0·11	Do.	Do.	Dull black, with glossy patches, very soft and soapy to touch, clean.
								Punjab.									
7070 and 7071	7083 and 7084	3rd Feb. 1896	Dandot	Mining Manager, Colliery District, North-Western Railway.	Two boxes of Dandot steam coal.	11·16	5,995	38·32	13·10	51·42	41·49	7·09	0·000	1·86	Do.	Reddish white	Dull with bright patches, easily broken, clean.
7072 and 7073	7085 and 7086	Do.	Pidh	Do do.	Two boxes of Pidh steam coal. These are very friable and deteriorate rapidly if exposed to the air and when in bulk are apt to fire by spontaneous combustion.	11·61	6,237	39·44	10·00	49·44	43·86	6·70	0·006	3·20	Do.	Flesh colour	Clean, rather bright, easily broken, with little dust.

* Does not burn readily.

Indian invoice number.	Imperial Institute number.	Date.	Mine.	Whence received.	Remarks made in forwarding sample.	Evaporative power.	Calorific value.	Fixed carbon per cent.	Ash per cent.	Coke per cent.	Volatile matter per cent.	Moisture per cent.	Phosphorus per cent.	Sulphur per cent.	Caking properties.	Colour of ash.	Other characteristics of the coal.
					B.—GONDWANA COALS—*contd.*												
					Bengal: Raniganj field—*concld.*												
					(a) *Raniganj series*—concld.												
1668	2872	4th Oct. 1894	Sanctoria	Bengal Coal Company, Limited.	Sanctoria Coal	11.78	6,325	49.32	10.74	60.06	36.69	3.25	0.204	1.53	Cakes	Yellowish grey	A dull coal with bright patches, hard and clean.
					(b) *Barakar series.*												
7746	7317	26th June 1896	Petana	Messrs. Mylne & Co., Proprietors, Petana Colliery, Barakar.	Petana Steam Coal	12.88	6,920	54.38	10.44	64.82	32.73	2.45	0.019	0.83	Do.	Dirty white	Glistening coal composed of dull and bright portion, former tough, the latter readily broken. Occurs in well-defined layers.
*1659	2863	4th Oct. 1894	Laikdih	Bengal Coal Company, Limited.	Laikdih Coal	12.52	6,721	57.70	8.62	66.32	31.45	2.23	0.034	0.53	Do.	White	Mixed dull black and glossy, the latter crumbles readily, clean.
*99	1448	Do.	Kumardubhi	Barakar Coal Company, Kumardubhi Colliery.	......	12.23	6,567	51.48	13.85	65.33	32.81	1.86	0.024	0.53	Do.	Grey	Layers of dull and bright coal, clean, rounded fracture.
8261	7757	13th July 1896	Patlabari	South Barakar Coal Company, Patlabari Colliery, No. 2, Seam.	.....	12.41	6,666	57.15	11.30	68.45	29.83	1.72	0.360	0.63	Do.	Reddish grey	Dull coal with bright layers, easily broken with much dust, dirty to handle.
7865	7311	Do.	Kumardubhi	Barakar Coal Company	One box of steam coal from Kumardubhi Colliery.	12.09	6,490	51.35	14.95	66.30	32.06	1.64	0.148	0.63	Do.	Dove	Dull with bright patches, fairly tough and clean.
*652	1996	14th Oct. 1894	Barakar	Barakar Iron Works	...	11.10	5,962	53.40	18.33	71.82	26.57	1.61	0.140	0.62	Do.	Greyish white	Dull, black, dirty, very hard.
7247	7099	28th Mar. 1896	Do.	New Barakar Coal Company, through G. Alexander, Esq.	Coal taken from an incline just being opened out, situated three miles from Barakar on the Jherria Branch Railway. Taken from about 10 feet below the surface.	10.09	5,410	41.80	29.25	71.05	27.47	1.48	0.014	0.89	Do.	Dirty white	Dull black coal with bright patches in places, cleaves occasionally with a silky fracture, clean.
7194	7097	20th Mar. 1896	Borrea	Managing Agents, Borrea Coal Company.	Salanpur Coal	11.57	6,215	57.31	14.86	72.17	26.53	1.30	0.016	0.75	Do.	Greyish white	Dull silky coal with glistening layers and patches. Hard and brittle, very clean.
8084	7452	11th Aug. 1896	Do.	Managing Agent, New Beerbhoom Coal Company.	Coal from Borrea fourth seam.	13.01	6,985	55.92	12.30	68.22	30.50	1.28	0.012	0.95	Do.	Dirty pink	Dull with bright patches, breaks easily in layers, clean.
7[illegible]95	7455	29th July 1896	Khusari, Mugma, East Indian Railway.	A. Whyte, Esq., Raniganj.	Coal from the village of Khusari belonging to Pandra Estates, eight miles north-west of Barakar. In this seam a band of 2 feet very dark and carbonaceous clay divides the seam into two; the top coal is 5 feet 6 inches in thickness, of bright appearance, the bottom coal is 6 feet 6 inches in thickness, and is a heavier and duller-looking coal.	12.90	6,930	59.01	11.96	70.97	27.83	1.20	0.146	1.89	Do.	Dirty fawn	A dull silky coal with bright patches breaks easily, clean.
7740	7323	25th June 18 6	Rajpur	Manager, Rajpur Coal Company, Barakar.	Coal from Rajpur Colliery, as usually obtained.	11.78	6,325	55.05	18.95	74.00	24.88	1.12	0.011	0.47	Does not cake	Dirty white	A dull coal with bright patches, fairly tough, conchoidal fracture.

* Does not burn readily.

Indian invoice number.	Imperial Institute number.	Date.	Mine.	Whence Received.	Remarks made in forwarding sample.	Evaporative power.	Calorific value.	Fixed carbon per cent.	Ash per cent.	Coke per cent.	Volatile matter per cent.	Moisture per cent.	Phosphorus per cent.	Sulphur per cent.	Caking properties.	Colour of ash.	Other characteristics of the coal.
B.—GONDWANA COALS—*contd.*																	
Bengal: Jherria field.																	
Barakar series.																	
8196	7772	25th Nov. 1896	Choitoodih	Katras-Jherria Coal Company, Limited.	Choitoodih No. 15 Seam	12·64	6,787	61·24	11·46	72·70	25·45	1·85	0·033	0·93	Cakes	Dirty white	Bright coal in layers, breaks easily, clean.
8195	7771	Do.	Mulkera	Do do.	Mulkera., West Colliery No. 15 Seam.	11·84	6,358	58·64	13·15	71·79	26·44	1·77	0·040	0·75	Do.	Reddish grey	Bright coal in layers, clean.
7866	7312	13th July 1896	Loyabad	Manager, Barakar Coal Company.	Steam coal from Loyabad Colliery.	11·88	6,380	60·54	13·04	73·58	24·99	1·43	0·045	0·87	Do.	Light grey	Exhibits a peculiar curved fracture. Part of the sample was of dull appearance and very tough, while the remainder was bright and broke readily into small fragments.
7866	7312	Do.	Do.	Do. do.	Do. (a special piece which was roughly ovoidal).	11·92	6,402	55·69	18·56	74·25	24·21	1·54	0·119	0·91	Do.	Do.	
8329	7767	25th Nov. 1895.	Kustore	Raniganj Coal Association, Limited.	Coal from Kustore Colliery, Jherria.	12·41	6,666	63·71	8·58	72·29	26·31	1·40	0·124	0·61	Do.	Reddish white	Dull coal with graphitic lustre in oval pieces, and conchoidal fracture, breaks easily in layers with some dust, clean to handle.
8260	7766	25th Feb. 1897.	Do.	Do. do.	Do. do.	12·37	6,644	63·21	9·14	72·35	26·33	1·32	0·053	0·50	Do.	Dirty white	Dull coal with bright layers, clean.
8192	7768	25th Nov. 1896.	Chattabad	Katras-Jherria Coal Company, Limited.	Chattabad No. 12 Seam	12·70	6,820	62·17	11·38	73·55	25·17	1·28	0·012	0·85	Do.	Greyish red	A clean rather bright coal, easily broken.
7248	7100	28th Mar. 1896.	Jherria	Bengal-Nagpur Coal Company, Limited, through George Alexander, Esq.	Coal taken from inclines at Buggutdiha in Jherria.	10·70	5,747	56·35	17·88	74·23	24·49	1·28	0·089	0·90	Do.	White	Bright glistening coal, brittle and hard, in places has a pitchy appearance.
8723	8120	25th Feb. 1897	Koiloodee	Jherria Coal Company, Katras Collieries, Manbhum.	Koiloodee No. 12 Seam	11·92	6,402	60·23	15·90	76·13	22·71	1·16	0·233	0·83	Do.	Dirty white	Rather bright coal with a silky lustre, breaks easily with some dust.
8194	7769	25th Nov. 1896	Mulkera	Katras-Jehrria Coal Company, Limited.	Mulkera South Colliery, No. 14 Seam.	12·42	6,672	58·85	14·36	73·21	25·64	1·15	0·098	0·83	Do.	Do.	Dull coal with bright layers, clean.
7249	7101	28th Mar. 1896	Jherria	Bengal-Nagpur Coal Company, Limited, through George Alexander, Esq.	Coal taken from a quarry at Buggutdiha. These two samples are not only surface coal but have been exposed to the atmosphere.	10·24	5,500	54·25	24·20	78·45	20·52	1·03	0·203	0·70	Do.	Light grey	Dull black coal with bright patches in places, cleaves occasionally with a silky fracture, rather hard, fairly clean.
8193	7770	25th Nov. 1896	Mulkera	Katras-Jherria Coal Company, Limited.	Mulkera East Colliery, No. 13 Seam.	12·66	6,798	62·60	10·55	73·15	25·99	0·86	0·023	0·93	Do.	Dirty white	Laminated bright coal, dirty, breaks very easily, with much dust.
Bengal: Giridih field.																	
Barakar series.																	
*641	1985	4th Oct. 1891	Karharbari	East Indian Railway, Karharbari Colliery, Upper Seam.	......	13·01	6,985	66·80	5·35	72·15	26·57	1·28	0·040	0·40	Does not cake	Yellowish brown	Dull black, hard, clean, breaks into cubes.
*1662	2866	6th Jan. 1896	Kuldiha	Superintendent, Bengal Coal Company, Limited.	Kuldiha Coal	12·39	6,657	61·20	12·08	73·28	25·46	1·26	0·007	1·50	Cakes	White	A dull black coal, clean and hard.
*639	1983	4th Oct. 1894	Karharbari	East Indian Railway, Karharbari Colliery, Lower Seam.	......	12·37	6,644	64·80	7·37	72·17	26·60	1·23	0·015	0·42	Do.	Dark yellow	Dull black, clean, not very hard.

* Does not burn readily.

Indian invoice number.	Imperial Institute number.	Date.	Mine.	Whence Received.	Remarks made in forwarding sample.	Evaporative power.	Calorific value.	Fixed carbon per cent.	Ash per cent.	Coke per cent.	Volatile matter per cent.	Moisture per cent.	Phosphorus per cent.	Sulphur per cent.	Caking properties.	Colour of ash.	Other characteristics of the coal.
					B.—GONDWANA COALS—*contd.*												
					Bengal: Giridih field—*concld.*												
					Barakar series—concld.												
*636	1980	4th Oct. 1894	Karharbari	East Indian Railway, Karharbari Colliery, Jogitand Seam.	......	13·11	7,040	56·45	10·77	67·22	31·77	1·01	0·006	0·51	Cakes	White	Laminated, very clean, cleaves in small cubes.
7014	7081	31st Jan. 1895	Do.	Manager, Giridih Colliery Company, Limited.	(Karharbari Lower Seam) from Pit Paharidih, Giridih Coalfield.	12·13	6,512	58·59	14·55	73·14	25·85	1·01	0·022	0·45	Do.	Dove	Dull, rather tough, breaks in every direction with little dust.
6817	7070	6th Jan. 1895	Giridih	Superintendent, Bengal Coal Company, Limited.	Steam Coal, Giridih	13·37	7,183	60·93	9·99	70·92	28·19	0·89	0·025	0·43	Do.	Buff	Clean but rather dusty, crumbles readily, bright in layers.
					Bengal: Daltonganj field.												
7145	7090	6th Mar. 1896	Daltonganj	Dr. W. Saise	Daltonganj Coal, Rajhara Seam.	10·41	5,591	62·35	14·04	76·39	21·38	2·23	0·0021	0·93	Does not cake	Yellowish brown	Bright coal, rather hard, not very dirty, on some pieces a small amount of white deposit.
					Central India.												
7095	7093	15th Feb. 1896	Umaria	The Manager, Umaria Colliery.	Sample from No. 2 Seam, Northern area.	9·94	5,337	45·99	14·94	60·93	33·20	5·87	0·003	1·02	Do.	White	Similar to 7093, traces of iron pyrites in cleavages, rather tough.
7096	7094	Do.	Do.	Do. do.	Sample from No. 3 Seam, Northern area.	10·21	5,481	50·38	14·98	65·36	29·72	4·92	0·003	1·81	Do.	Do.	Similar to 7093, but not so dirty to handle. It also shows a silky patched appearance when cleaved.
7927	7449	22nd July 1896	Do.	Do. do.	Sample from No. 4 Seam, Northern area	10·55	5,665	43·42	21·07	64·49	31·21	4·30	0·012	1·89	Do.	Reddish white	Tough coal of dull appearance, cleaving in layers.
7093	7091	15th Feb. 1896	Do.	Do. do	Sample from No. 3 Seam, middle area.	11·06	5,940	63·63	15·99	79·62	17·28	3·10	0·021	0·76	Do.	White	Small quantities of white substance between the layers in places. Rather dirty to handle.
*256	1605	4th Oct. 1894	Do.	Do. do.	......	10·04	5,390	59·65	23·63	83·28	13·92	2·80	0·015	0·32	Do.	Do.	A clean dull coal with irregular cleavage, easily broken.
*322	1671	Do.	Do.	Do. do.	......	9·77	5,247	55·97	26·60	82·57	14·70	2·73	0·003	0·43	Do.	Greyish white	Dull, soft, clean, and contains fossilized resin.
7094	7092	15th Feb. 1896	Do.	Do. do.	Sample from No. 2 Seam, middle area.	10·14	5,445	56·66	23·17	79·83	17·63	2·54	0·003	1·09	Do.	White	Similar to 7093.
7928	7450	22nd July 1896	Do.	Do. do.	Sample from No. 4 Seam, middle area. "Information required as to their caking properties."	10·83	5,819	48·99	24·28	73·27	25·15	1·58	0·004	2·03	Do.	Dirty white	Dull, with small bright patches, irregular cleavage, easily broken, with much dust, dirty.
					Central Provinces.												
318	1667	...	Warora	Warora Colliery	......	10·24	5,500	40·97	12·78	53·75	37·09	9·16	0·005	1·21	Do.	White	A clean silky coal, easily broken cleaving in cubes.
8131	7760	1st Sept. 1896	Do.	Do. do.	From No. 4 Pit	9·46	5,082	43·12	15·80	58·92	31·98	9·10	0·008	2·37	Do.	Greyish white	Same as 8130.

* Does not burn readily.

Indian invoice number.	Imperial Institute number.	Date.	Mine.	Whence Received.	Remarks made in forwarding sample.	Evaporative power.	Calorific value.	Fixed carbon per cent.	Ash per cent.	Coke per cent.	Volatile matter per cent.	Moisture per cent.	Phosphorus per cent.	Sulphur per cent	Caking properties.	Colour of ash.	Other characteristics of the coal.
					B.—GONDWANA COALS—*concld.*												
					Central Provinces—*concld.*												
8130	7779	1st Sept. 1896	Warora	Manager, Warora Colliery.	From No. 2 Pit	10·27	5,514	39·96	11·86	51·82	39·17	9·01	0·009	0·98	Does not cake	Greyish white	Slaty dull coal with some brighter patches, rather dirty.
*316	1065	...	Do.	Do. do.	......	10·30	5,533	41·40	13·50	54·90	36·64	8·46	0·015	0·94	Do.	White	Dull, with bright patches, clean and rather soft.
8132	7759	1st Sept. 1896	Do.	Do. do.	From No. 5 Pit	9·93	5,335	44·57	12·75	57·32	34·33	8·35	0·002	0·77	Do.	Dirty white	Same as 8130.
8133	7773	Do.	Do.	Do. do.	From No. 1 Seam, No. 2 Pit.	9·01	4,840	40·97	20·75	61·72	30·70	7·58	0·017	0·64	Do.	Slightly yellow.	Slaty dull coal, with only a few bright spots, dirty, rather tough.
*1651	2855	4th Oct. 1894	Mohpani	The Nerbudda Coal and Iron Company, Limited, Mohpani	No. 4 Seam	11·39	6,116	45·35	9·23	54·58	38·35	7·07	0·008	0·43	Cakes	Light yellow	Dull, hard and clean, with occasional glossy layers.
8280	7777	Do.	Do.	Do. do.	Sample C	9·42	5,060	50·81	11·93	62·74	30·81	6·45	0·038	1·03	Does not cake	Terra cotta	A dull coal with some bright layers, breaks easily with much dust, very dirty.
*1650	2854	Do.	Do.	Do. do	No. 3 Seam	10·36	5,566	41·00	19·65	60·65	33·40	5·95	0·541	0·44	Cakes	Yellowish brown	Dirty, alternate layers of dull and very hard coal and bright coal, easily broken.
*1649	2853	Do.	Do.	Do. do.	No. 2 Seam	9·91	5,314	42·61	20·13	62·74	31·43	5·83	0·037	0·39	Do.	White	
8284	7775	Do.	Do.	Do. do.	Sample A	11·84	6,358	49·83	8·88	58·71	35·89	5·40	0·052	0·52	Does not cake	Light fawn	A shaly coal, dull, with bright spots in layers, breaks easily, dirty, gives much dust.
8285	7776	Do.	Do.	Do do.	Sample B	11·80	6,336	60·64	8·33	68·97	25·67	5·36	0·091	0·47	Do.	Do.	A dull coal very light, breaks easily, much dust, very fibrous.
*1648	2852	Do.	Do.	Do. do	From No. 1 Seam	9·50	5,104	42·46	24·30	66·76	28·45	4·79	0·011	0·50	Do.	Brownish yellow.	Dull, laminated, very hard, fairly clean.
					Nizam's Dominions.												
*87	1436	...	Singareni	Hyderabad	......	10·32	5,544	43·55	12·71	56·26	36·34	7·40	0·002	0·29	Do.	Yellowish brown	Irregular fracture, extremely hard, dull clean coal with thin streaks of glossy coal.
7803	7308	...	Do.	Agent and General Manager, Hyderabad (Deccan) Company.	Singareni Coal	10·96	5,885	54·68	8·16	62·84	30·01	7·15	0·009	1·28	Cakes slightly	Dark fawn	Very tough, dull with bright patches.

* Does not burn readily.

SUGGESTIONS FOR A CLASSIFICATION OF THE VINDHYAN SYSTEM. BY E. VREDENBURG, A.R.C.S., *Deputy Superintendent, Geological Survey of India.*

THE general scheme of classification of the Vindhyan system which, for many years, has been adopted in all the publications of the Geological Survey of India, is as follows:—

(II) Upper Vindhyans	Bhander. Rewa. Kaimur.
(I) Lower Vindhyans.	

The names Kaimur, Rewa and Bhander were originally applied by Dr. T. Oldham to three conspicuous sandstone bands which, owing to the softer strata, mostly shales and limestones, separating them, constitute well-marked conspicuous scarps in the eastern part of Central India.[1] In their main features, the divisions thus outlined, are remarkably constant, the distinctness of their petrological characters enabling their identification to be carried out with a great degree of confidence throughout the vast area occupied by the rocks of the Vindhyan system, in spite of their unfossiliferous nature.

Dr. Oldham's classification was adopted by H. B. Medlicott in his description of the geology of Bundelkhand published in 1860.[2] Between the years 1860 and 1869, considerable surveys were performed in various portions of the Vindhyan area, the results of which are incorporated in Mallet's monograph of the "Vindhyan Series," which remains, to this day, the most complete work as yet written on that subject.[3] In this work, the classification proposed is far more elaborate than Dr. Oldham's original scheme. For the Upper Vindhyans it is as follows:—

Bhander	Upper Bhander	Upper Bhander sandstone
	Lower Bhander	Sirbu shales. Lower Bhander sandstone. Bhander limestone. Ganúrgarh shales.

[1] Journ. As. Soc., Bengal, Vol. XXV, p. 253 (1856).

[2] On the Vindhyan rocks and their associates in Bundelkhand. Mem., Geo. Surv. of India, Vol. II, part 1.

[3] On the Vindhyan series, as exhibited in the North-Western and Central Provinces. Mem., Geol. Surv. of India, Vol. VII, part 1 (1869).

Rewa	Upper Rewa	Upper Rewa sandstone.
	Lower Rewa	Jhiri shales. Lower Rewa sandstone. Panna shales.
Kaimur	Upper Kaimur	Upper Kaimur sandstone. Kaimur conglomerate.
	Lower Kaimur	Bijaigarh shales. Lower Kaimur sandstone.

The Lower Vindhyans received separate classifications for their two principal outcrops, in the Son valley and in Bundelkhand.

These numerous zones of the Upper Vindhyans cannot be followed out from place to place with so much certainty as the broader divisions of the older classification. Although the surveys performed by Mallet and his colleagues covered enormous areas, they had not been linked together when the monograph was published. Up to the present day, there still remain large gaps of unknown or imperfectly surveyed ground, so that the only sure test to be relied upon for identifying unfossiliferous rocks, that is continuity of outcrops, is not available. Some of the subdivisions are more easily recognised than others, either on account of their well-marked lithological characters, or because they happen to occupy regions that have benefited by a greater continuity of survey. Such are the Kaimur conglomerate and the Lower Bhanders. But a considerable degree of doubt remains concerning the Lower Rewas of Mallet's classification: at some places, between the Upper Rewa sandstone and the sandstone regarded as Upper Kaimur, there intervenes only one shale band, while at other places there are two shale bands and an intermediate sandstone. The surveys along the belt occupied by the Lower Rewas are too discontinuous to ascertain in what manner the single shale band of certain localities is related to the triple subdivision observed elsewhere. The question is by no means so trivial as it might appear; for it is precisely in the Lower Rewa that the principal diamond-bearing zone of Bundelkhand occurs. In attempting to trace the possible extension of the gem into other localities where it may have remained hitherto unobserved, it would be a great advantage if it were possible to detect, at any one particular locality, the exact stratigraphical equivalent of the diamond-bearing zone of Bundelkhand.

My examination of the diamantiferous tract of Panna in the spring of 1905 led me to enquire into the subject of this classification. It is only in Gwalior territory, about 150 to 200 miles west or north-west of

Bundelkhand, that two shale bands and an intervening sandstone occur sufficiently balanced in their respective importance to justify a classification like that proposed by Mallet. The thickness of each shale band is close upon 200 feet, while the intervening sandstone reaches 300 feet.[1] At the eastern extremity of the Rewa outcrop, about 130 miles east of Panna, Mallet recognises the existence of only one shale band, some 500 feet thick. At Barokar Khas, about 100 miles east of the Bundelkhand diamond mines, a sandstone layer, less than 10 feet thick, occurs about midway through the shales. It increases in thickness on approaching Bundelkhand, and, relying upon the fragmentary evidence then available, Mallet came to the conclusion that the increase in thickness of this Lower Rewa sandstone is maintained westward throughout Bundelkhand, and that the band is continuous with the 300-foot thick sandstone of Gwalior territory still further west. Accordingly, he supposed that at Panna, where the best known of the diamond mines are situated, the Lower Rewa consists, as in Gwalior, of two shale bands with an intervening sandstone. The diamonds occur at the very base of the Lower Rewa, and therefore, according to this supposition, in the lower of the two shale bands, which, on this account, received the name of Panna shales. The supposed upper shale band was named after Jhiri, a locality in Gwalior territory, situated on the outcrop of the upper of the two shale bands which, there, really do exist separate.

Subsequently to the publication of Mallet's Memoir, a detailed survey of Bundelkhand was undertaken by W. L. Willson from 1873 to 1877 with the advantage of a new set of admirably accurate topographical maps which had then just been issued by the Survey of India. At Panna, Willson's map shows only one shale band between the Upper Kaimur and Upper Rewa without any Lower Rewa sandstone. In the neighbourhood of Itwa, 13 miles east of Panna, Willson's map does indicate a subsidiary sandstone of small thickness, not indeed midway through the Rewa shales, but amongst their lowermost strata, in a very different position therefore from the sandstone band described by Mallet as occurring some 100 miles further east at Barokar Khas. It is not possible to say whether the sandstone at Itwa is in any way related to the one at Barokar Khas, because the intervening country east of Itwa has not been surveyed in detail. But west of Itwa, between Itwa and Panna, the subsidiary sandstone dies out

[1] Mem., Geological Survey of India, Vol. VII, p. 71.

entirely as is clearly shown in Wilson's survey, and as I have been myself able to verify. At Panna, therefore, there is no Lower Rewa sandstone to split up the Rewa shales into two separate portions, and the name "Panna shales" applied to one of these imaginary subdivisions cannot be retained. Moreover, as there is another gap between the detailed surveys of Bundelkhand and those of Gwalior territory further west, it is impossible to say how the two shale bands of the latter tract are connected with the single shale band constituting the Lower Rewa at Panna. Of the two shale bands in Gwalior, it is quite possible that the upper band known as the Jhiri shales is the only one that corresponds with the Lower Rewa of Bundelkhand, and that the massive rock described as Lower Rewa sandstone in Gwalior is equivalent to some of the rocks elsewhere included in the Kaimur. The evidence derived from the surveys at present progressing in Central India point to some such correlation, but it is unnecessary to go into details so long as these observations lack the confirmation that can only be obtained when they have been finally connected. In the following report on the Panna diamond mines the name "Jhiri shales" has been provisionally retained and is applied to the single shale band of the Lower Rewa as developed in Bundelkhand.

It is now evident that the scheme proposed in Mallet's monograph is not applicable to the entire Vindhyan area, and the author himself was aware of the possible necessity of altering it, at least in the western portion of the Vindhyan outcrop.[1] A great deal of uncertainty prevails as to whether certain rocks of this western area belong to the Kaimur or Rewa, and, under such circumstances, it would be advantageous to unite the two into one group. This is not merely a matter of temporary convenience, but it would help to give a more symmetrical disposition to the Vindhyan classification. Thus united into a single division, the Kaimur and Rewa become essentially a group of sandstones, amongst which the shales and limestones only play a subordinate part. The same is the case with the great mass of sandstones constituting the Upper Bhander. On the other hand, the Lower Bhander and Lower Vindhyans are essentially shaly and calcareous formations, at least wherever they are most characteristically developed. Moreover, as regards relative importance, the numerous formations grouped together as Lower Bhander have a thickness out

[1] Mem., Geological Survey of India, Vol. VII, p. 89. This refers to some subdivisions of the Lower Bhander.

of all proportion with the comparatively insignificant subdivisions, classified as Lower Rewa and Lower Kaimur. Indeed their aggregate thickness often exceeds the sum of all the strata constituting the Kaimur and Rewa. While therefore the division of the Bhander into a lower, mainly shaly, division and an upper, mainly arenaceous, one is quite appropriate, it would be useful, in order to obtain a balanced classification, to give one general name to the remainder of the Vindhyans including all the rocks hitherto known as Lower Vindhyans, Kaimur and Rewa. They might be called the Ken series, from the well-known river of that name whose course traverses the outcrop of most of these subdivisions. We would then have an Upper Ken series mainly arenaceous, including the Rewa and Kaimur, and a Lower Ken series, mostly shaly, including the rocks hitherto known as Lower Vindhyans.

The separation of this lower series under the name of Lower Vindhyans gives it an importance out of all proportion with its position in the stratigraphical scale. The unconformity locally detected between these beds and the overlying Kaimur has been chiefly relied upon to justify this separation. But besides being only local, features of this kind are not confined to the Lower Vindhyan and Kaimur junction: similar unconformities occur within the Lower Vindhyans themselves, for instance between the Semri and Palkua divisions in Bundelkhand, while irregularities of a similar character, though less pronounced, occur within the Upper Vindhyans also. The formation of the synclinal trough in which the Vindhyans were deposited proceeded *pari passu* with their sedimentation, so that, along the edges of the syncline some of the older divisions became upheaved and exposed to denudation while sedimentation continued uninterrupted nearer the axis of the syncline. This explanation reconciles the indications of a perfectly conformable sequence exhibited by certain sections with the apparently conflicting evidence furnished by the frequent occurrence, in the Vindhyan conglomerates, of fragments derived from a lower zone of the same system.

The name "Son series," frequently used in manuscript by Medlicott, might be applied to the Lower Vindhyans, especially as they are nowhere more typically developed than along the Son valley. A corresponding name for the Kaimur and Rewa united into one series might be borrowed from the river Tons whose drainage area is almost entirely situated upon the broad tableland constituted by the Kaimur and Rewa rocks in the eastern part of the Vindhyan outcrop. Owing

to their comparative softness, the rocks constituting the Lower Bhanders do not rise into conspicuous ridges or plateaux like the massive sandstones of the Upper Bhander or of the Tons (Kaimur and Rewa) series, but, like the Son (Lower Vindhyan) series, they form flat or gently-undulating regions, such as the fertile elevated valley-plain in southern Bundelkhand known as the "Haveli," which extends through a length of 120 miles and a breadth of 16 between the dip-slope of the Upper Rewa sandstone to the north, and the escarpment of the Upper Bhander sandstone to the south. The name "Haveli series" would be a suitable one for the Lower Bhander. Lastly, to complete the symmetry of this scheme, the Upper Bhander might be named "Betwa series" after the river of that name which flows through Upper Bhander sandstone for many miles in Bhopal.

The amended classification of the Vindhyans might then be tabulated as follows :—

		Approximate thickness in feet.	Composition.
Bhander .	Betwa series . .	500	Sandstones.
	Haveli series . .	1,400 to 2,000	Mostly shales and limestones with subordinate sandstone.
Ken .	Tons series (including Rewa and Kaimur).	1,200 to 1,600	Mostly sandstones, with subordinate shales and limestones.
	Son series (corresponding with the Lower Vindhyans).	0 to 2,000	Mostly shales and limestones with subordinate sandstones.

It may be noticed that this scheme, which is offered only tentatively, does not aim at displacing the older classification, but merely rearranges it. The names "Kaimur" and "Rewa" are retained for the strata to which they were originally applied, attention being drawn merely to the fact that these terms do not refer to divisions of the same rank as the term "Bhander." The older division not only fails to give a balanced classification of the rocks included within the Vindhyan system, but, owing to its elaborateness, it is apt to convey a

false impression regarding the relative importance of the Vindhyans amongst the other ancient systems of the Peninsula. In the classification published in the Manual of the Geology of India, the division of the Kadapahs of southern India into Pápaghni, Cheyair, Nallamalai and Kistna,[1] appears comparable with the division of the Upper Vindhyans into Kaimur, Rewa and Bhander; whether intentionally or not, an impression is conveyed that the Kadapahs and the overlying Karnuls stand in very much the same relation to one another as the Lower and Upper Vindhyans, instead of which it is only the Karnuls that correspond with the Vindhyans, whether upper or lower is at present uncertain and immaterial, while the Kadapahs include three or four unconformable systems equal in importance to the Vindhyans, one of which, the Cheyair, equivalent to the Bijawar (also called Gwalior) of the northern part of the Peninsula, is a system vastly older than the Vindhyans.

In the following note upon the diamond-bearing zone of Panna, an attempt has been made to distribute the Vindhyan strata of Bundelkhand according to the plan above outlined (Pl. 23).[2]

Regarding the exact correlation of the smaller subdivisions of Bundelkhand as shown in this diagram with those of other regions, various points still remain doubtful that can only be elucidated by extending the present surveys.

[1] Second ed., p. 78.

[2] This diagram had already been printed when the above note was written. In accordance with the nomenclature adopted by the Geological Congress, the term *subsystem* or *series* might be substituted for the term *group* which, hitherto, has been used by the Geological Survey of India to denote the major divisions of a system. I have avoided using the word *étage* or *stage*, which sounds to me somewhat out of place when applied to unfossiliferons rocks.

GEOLOGY OF THE STATE OF PANNA, PRINCIPALLY WITH REFERENCE TO THE DIAMOND-BEARING DEPOSITS.

BY E. VREDENBURG, A.R.C.S., *Deputy Superintendent, Geological Survey of India.* (With Plates 23 to 26.)

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INTRODUCTION.

THE State of Panna consists of a number of more or less disconnected territories stretching over the length and breadth of Bundelkhand. Consequently, the geology of Panna is practically the geology of Bundelkhand.

The late Mr. H. B. Medlicott is the author of the most complete work yet written on the geology of that province (Memoirs, Geological Survey of India, Vol. II, pages 1—95, 1860).

Detailed geological maps on the scale of one inch to the mile including the whole of Bundelkhand were prepared by the late Mr. W. L. Willson during the years 1873 to 1877.

These maps have never yet been published. The essential features of the geology of Bundelkhand can be recognised on the map illustrating Mallet's monograph of the "Vindhyan Series" (Memoirs,

Geological Survey of India, Vol. VII, part 1). From the time of Willson's survey up to the date of my visit to Panna, Bundelkhand has not been examined by any other officer of the Geological Survey except on the occasion of a visit by the late Dr. King, who gave a short report on the diamond mines.

I saw the mines at the end of March and during part of April 1905. This is the best time of the year for observing some of the most interesting and important workings, those connected with the diamantiferous conglomerate near the town of Panna, at the base of the Lower Rewa division of the Vindhyans. A certain number of gems are extracted from a second conglomerate situated in the uppermost beds of the "Upper Rewa" and these are actively worked only during the rainy season (July to September) and just after.

CHAPTER I.—GEOLOGICAL DIVISIONS.

I.—Physical features.

IN the territories constituting the Panna State, there is a well-marked correspondence between physical and geological features, such as characterises a region that has been for a long time subjected to the simple action of denudation.

Bundelkhand consists of two very different regions: a northern one which is mostly a comparatively low-lying granitic plain, and a southern more elevated tract consisting of sedimentary rocks amongst which sandstones predominate or at least form a very large proportion. A contour line drawn at an altitude of about 800 feet would almost exactly coincide with the geological boundaries between the crystalline and sedimentary formations. The boundary between these two geological formations follows the northern escarpment of the southern upland. The granitic plain varies in altitude from about 700 feet along the foot of the scarp to about 500 feet some 50 miles further north, where the granitic surface gradually sinks beneath the alluvium of the Gangetic plain. Except very locally where that rock is perhaps more compact than usual, the granite proper seldom rises into hills, but the granitic plain is traversed at intervals by abrupt wall-like ridges, which are veins consisting of quartz. This vein-quartz resists denudation far more successfully than ordinary granite, and, consequently, stands out in ridges, just for the same reason as the southern upland has maintained a higher level than the general surface of the granitic plain, because the

sandstones that enter so largely into its constitution also resist denudation far better than granite.

2.—List of geological formations.

The following formations are met with in Panna territory :—

7. Recent and sub-recent alluvium, soil, and calcareous tufa.
6. Laterite.
5. Deccan Trap.
4. Lameta.
3. Vindhyan.
2. Bijáwar.
1. Archæan.

The oldest of these, the Archæan (1), which consists entirely or nearly so of the granitic formation just mentioned, is confined, as already explained, to the lowland of northern Bundelkhand. The Vindhyan formation (3) forms all the upland of southern Bundelkhand, the Bijáwar (2) intervening locally between it and the granite. The only important outcrop of Deccan Trap (5) in the Panna State is in the westernmost district, in the neighbourhood of Baxwaho. It also plays a subordinate part in some small but conspicuous hills rising above the highest portions of the broad Vindhyan sandstone ridge to the south-west of Panna. In these hills it is associated with Laterite (6). The lateritic formation is widely spread over southern, or Upper, Bundelkhand, either in the form of compact masses forming more or less extensive flat-topped hills, or else disseminated in varying proportion in the shape of nodules through the surface soil. The proportion is sometimes so great that the soil becomes a lateritic gravel.

Ordinary alluvial soil (7) of varying thickness occurs over a great portion of the broader river-valleys, and occupies large areas both in the southern part of Bundelkhand (especially in the broad, flat valley-plain known as the "Haveli"), and in northern Bundelkhand, where it gradually merges into the Gangetic alluvium.

Another sub-recent formation of some importance is the calcareous tufa which has accumulated in some of the river-gorges.

3.—The Bundelkhand Granite.

So far as regards the Panna State, the Bundelkhand Granite constitutes practically the whole of the Archæan system. A short description of this formation has been published by the late Mr. H. B. Medlicott (Mem., Geol. Survey of India, Vol. II, pages 49–50). I

have only incidentally examined these rocks and cannot add much information to that obtained by my predecessor.

The Bundelkhand granite is a medium to coarse-grained typical granite consisting of quartz, felspar, principally of the orthoclastic variety, and hornblende. The great prevalence of orthoclase felspar in large cleavable crystals, usually pink in colour, gives the rock its characteristic appearance. The quartz is whitish or bluish-grey and translucent. The hornblende is of a dark colour; it is not very abundant. Other minerals are found but sparingly.

The uniformity of the granitic outcrop is diversified by the great quartz reefs already alluded to as a conspicuous physical feature in northern Bundelkhand. They form a system of abrupt almost rectilinear ridges bearing approximately north-east. Another interesting feature of the granitic area consists in a second set of numerous linear dykes of basic igneous rock, many of which intersect the direction of the great quartz-veins approximately at right angles. These dykes appear to represent a period of volcanic activity contemporaneous with the Bijáwar system. In southern India, similar dykes of the same age occur in great abundance in the neighbourhood of diamond-bearing deposits similar to those of Bundelkhand, an association which suggests some possible genetic relation.

4.—Possible representatives of the Aravalli Schists.

In the neighbourhood of the Dhasán (Dessaun) river, a region which is physically, though no longer politically, a part of Bundelkhand, there are some rocks which, from the short descriptions available, appear to include representatives of series older than the Bundelkhand granite and belonging to the system known as Arávalli or Dharwar. Typical representatives of this ancient series do not seem to extend eastwards into the region occupied by the independent States of Bundelkhand. Nevertheless, I noticed that near Pathar Chauki, on the road from Panna to Shahghát, the rocks immediately underlying the Lower Vindhyans, which have been mapped as Bijáwar by Mr. Willson, do not appear to be very typical of that formation. They consist, where I saw them, of a thin-bedded, faintly-banded quartzose rock of a whitish or greyish tint recalling to some extent the jaspers of the Bijáwar system, but with an appearance which is more that of vein-quartz than of jasper. The outcrop of these rocks is very narrow. Only a small fringe of the formation is visible between the overlying Vindhyans and the underlying granite. I have not observed their junction with the granite,

nor have I met with any description of this junction. It would be interesting to examine it if it is anywhere visible, for this would probably decide whether the age of the rock is Bijáwar or Arávalli; in the former case, the basement bed would be, no doubt, a conglomerate resting upon a denuded surface of the granite, while if the rocks belong to the Arávalli system, the junction should be of the transitional character peculiar to the contact of an intrusive rock with the older rocks into which it has been injected, for the Arávalli strata are older than the intrusive Bundelkhand granite.

In the exposure near Pathar Chauki the quartzose or jaspery layers are separated by micaceous films whose appearance suggests more the Arávalli than the Bijáwar system.

The dip of these rocks is very high, over 45° to the south. Such high dips are everywhere characteristic of the Arávalli formation.

5.—The Bijawar formation.

The great outcrop of ancient sedimentary rocks situated south, south-east and south-west of Bijáwar, a considerable portion of which is situated in Panna territory, constitutes the type area of the Bijáwar formation. For a detailed account, reference may be made to Mr. Medlicott's Memoir already quoted (Mem., G. S. I., Vol. II, pp. 35—48.)

I have not visited the area and cannot therefore add anything to the description. According to Mr. Medlicott's Memoir and Mr. Willson's map, the system consists of a basal sandstone succeeded by a massive limestone overlaid by shales interbedded with subsidiary limestones, jaspers and basic volcanic rocks. The caves near Dargama appear to be situated in the Bijáwar limestone.

The jasper beds of the Bijáwar are sometimes of a bright red colour due to the admixture of a varying amount of hæmatite. These red hæmatitic jaspers have a ribboned appearance due to the rapid alternation of layers of varying colour and composition, not unlike that of some very typical "ribboned schists" of the Arávalli and Dharwar systems, in which the proportion of iron is often so great that they become valuable iron ores. This high percentage of iron is sometimes met with in the Bijáwar formation itself, for instance near Gwálior, where rich iron ores are interbedded with rocks of that age. The famous iron ores of Bijáwar are, however, of a different nature, and appear to occupy areas of faulting or crushing, of the same nature as the iron ores found near the Narbada in the "Dhar forest" area.

These fault rocks often consist of a breccia whose matrix is a

mixture of silica and hæmatite of a brilliant red colour very similar in appearance to the bright red interbedded jaspers.

The Bijáwars were extensively disturbed before the deposition of the Vindhyans which rest upon them quite unconformably. Their denudation supplied the Vindhyans with a vast amount of material, the bright red pebbles derived from the bedded jaspers and fault-breccias being particularly conspicuous in some of the Vindhyan conglomerates.

6.—The Vindhyans.

The following table gives the constitution of the Vindhyan system in Bundelkhand, grouped in accordance with the classification outlined in the preceding paper :—

				Approximate thickness in feet.
BHANDER.	BETWA SERIES.		Upper Bhander sandstone . . .	500
BHANDER.	HAVELI SERIES.		Sirbu shales	800 to 1,000
			Lower Bhander sandstone . .	0 to 150
			Nagode limestone (sometimes with subsidiary shale band in upper portion) .	250
			Ganúrgarh shales . .	250
KEN.	TONS SERIES.	Rewa division.	Upper Rewa sandstone, with diamantiferous conglomerate in uppermost bed .	500 to 600
			Jhiri shales, with diamantiferous conglomerate at base, ocasionally with intercalation of subsidiary sandstone, shale and limestone, also at base . .	400
		Kaimur division.	Kaimur sandstone. Thinner-bedded upper portion . . .	200
			Kaimur sandstone. Thicker-bedded lower portion . . .	300
			Kaimur conglomerate	80
			Kaimur shales	0 to 150
	SON SERIES (LOWER VINDHYANS).	Palkua division.	Tirowan limestone	0 to 120
			Palkua shales	250
			Dalchipur sandstone, with conglomerate at base	0 to 90
		Semri division.	Semri shales	70
			Semri limestone	60
			Semri sandstone, with a variable amount of siliceous shales, and a basal conglomerate	100 to 250

These subdivisions have been represented on the diagram, Pl. 23.

This diagram shows the great importance of the sandstones which amount to about two-fifths of the total thickness of the formation. The main topographical features of the region are due to them. Conspicuous escarpments are formed by the three principal sandstone masses. The intervening shales and limestones usually form lower valleys largely covered with alluvium. Owing to their great thickness

it is the Lower Bhander strata that form the widest valley, a broad, elevated plain known as the "Haveli," remarkable for the highly-cultivated rich alluvium that covers it. The sandstone ridges have the usual shape assumed by a stratum with gentle dip, that is, a precipitous scarp on the side away from the dip, and a long dip-slope, nearly coinciding with the dip of the rock, extending from the crest of the escarpment up to the margin of the plain occupied by the softer overlying shales and limestones.

7.– Lower Vindhyan or Son series.

The Lower Vindhyan or Son series was originally known in Bundelkhand as the "Semri system" and is described in great detail, under that name, by H. B. Medlicott in the Memoir already referred to.

It contains the following subdivisions :—

Palkua division	7. Tirowan limestone.
	6. Palkua shales.
	5. Dalchipur sandstone.
	4. Dalchipur conglomerate.
Semri division	3. Semri shales.
	2. Semri limestone.
	1. Semri sandstone.

Compared with the remainder of the Vindhyan formation, the Lower Vindhyans are much more irregular in their mode of occurrence. This is partly because they rest upon an irregular surface of previous denudation, partly because, as mentioned in the preceding paper, they had already been disturbed and denuded to some extent before the deposition of the succeeding members. Not only is the Kaimur division unconformable to the Lower Vindhyans, but within the Lower Vindhyans themselves, the Palkua division is unconformable to the Semri. The Semri division, the lowest of all, was deposited upon an irregular and sloping surface of granite and shows therefore the greatest inequalities of original distribution. Before the deposition of the Palkuas, it was corrugated by earth-movements into shallow troughs and ridges, the Palkuas being then laid down mostly in the troughs. The whole series was again disturbed and denuded in the same manner before the deposition of the Kaimurs. The uppermost member, the Tirowan limestone, suffered most from this denudation and is therefore singularly irregular in its distribution. For the full detail of the distribution of these rocks, reference must be made to the very complete account given by Medlicott in his Bundelkhand

Memoir (pages 6—31) of which no more than a short summary can be given here.

The Semri sandstone, like all the other succeeding members, but more so than any of them, is limited in a north-western direction by the original sloping surface of the granite upon which it was deposited, this limitation being further increased by pre-Kaimur disturbance and denudation. Consequently, in some of the outliers that stretch beyond the main line of escarpment, such as the detached hills of Ajaigarh and Rajgarh, the Kaimurs rest directly on the granite surface, while in the main scarp and specially in the deep valleys that cut back through it, the Semri sandstone and various succeeding members of the Lower Vindhyans intervene.

An easily accessible outcrop of the Semri sandstones is crossed by the road from Panna to Shahghát, the best exposure being at the waterfall near Pathar Chauki. The lower part of the section consists of a hard siliceous rock of cherty nature more like an indurated shale than a sandstone, in thin irregularly rugose and warped laminæ, whose aggregate thickness amounts to some 150 feet. They are overlaid by about 30 feet of thick-bedded, highly indurated quartzitic sandstone forming a distinct ledge in advance of the Kaimur scarp. It is this ledge which causes the waterfall at Pathar Chauki.

At the base of the whole series, beneath the cherty laminated layers, there is another harsh sandstone in relatively thick beds, but of very small aggregate thickness. It is often conglomeratic, owing to the presence of small scattered pebbles of grey or whitish quartz. It does not contain red pebbles like those of the Kaimur conglomerate. It is exposed in the road-side of the Shahghát road, at some distance below Pathar Chauki, resting upon the highly contorted jaspery rocks which have already been alluded to as possible representatives of the Arávalli system.

Owing to the overlaps and irregularities already mentioned, the Semri limestones and shales and the Dalchipur sandstone are not exposed in the Shahghát road section: the Palkua shales directly overlap the Semri sandstones. The Semri limestone and shales outcrop at irregular intervals from the gorge of the Pasania river south of Chitrakot up to Saigarh in Bijáwar territory. (Some small discontinuous outcrops occur also further west near Bajno, and near Hirapur, north-west of Baxwaho.) The shales are remarkable for their coal-black colour which has several times caused them to be mistaken for coal, and for the presence of large lenticular limestone

concretions. Amongst the Semri strata in the valleys of the Bagain and of the Ranj, Medlicott mentions the occurrence of a peculiar quartzitic sandstone of a greenish colour and intensely hard, of a texture almost resembling that of jasper. Pebbles and boulders derived from this material are frequently met with in the diamantiferous conglomerates at the base of the Rewa shales, where they are locally known under the name of *kansya*.

The Dalchipur subdivisions, constituting the lowest beds of the Palkua division, are absent from the eastern part of the Lower Vindhyan outcrop. They do not commence until Chopra, a locality situated about 10 miles south-east of Bijáwar, and their outcrop runs from there westwards, mostly outside the limits of independent Bundelkhand. East of Chopra, the Palkua division does not contain any bed older than the Palkua shales: consequently, in the eastern exposures, the Palkua shales rest directly upon the Semri shales when both are present in the same section. For a detailed description of the Dalchipur sandstones and conglomerates, reference may be made to Medlicott's work.

The characteristics of the Palkua shales are very well described by Medlicott in the following terms: "The character of this rock is peculiar and constant: very fine, grey, weathering or bleaching white, generally thinly laminated, having a foliated aspect, often intensely hard almost approaching to jaspidification, generally breaking into angular subcubical pieces."

In the section already referred to along the Shahghát road, good exposures of the Palkua shales may be seen between Bakchor Chauki and Pathar Chauki.

The uppermost member of the Palkua division, the Tirowan limestone, is exposed at more or less irregular intervals from Tirowan up to the upper part of the Baráno river south of Bijáwar. It is usually a compact limestone, very regularly bedded. As already explained, its extent is greatly restricted owing to the double unconformity and overlap of the Palkuas with the Semris below and the Kaimur above.

8.—Upper Vindhyans.

The remainder of the Vindhyan system is usually known as "Upper Vindhyan." Its subdivisions have been described in great detail by F. R. Mallet in "The Vindhyan Series" (Memoirs of the Geological Survey of India, Vol. VII, part 1). These subdivisions are singularly constant in their characteristics along enormously developed outcrops, ex-

tending for hundreds of miles. Massive beds of fine-grained building stones are largely developed amongst the Upper Kaimur and Upper Bhander sandstones, in which valuable stone-quarries have been opened out at many places. Flaggy beds and false-bedding are very persistently developed in the Upper Rewa sandstone. The Upper Vindhyan shales consist of thin beds with very smooth and regular surfaces of parting, in which argillaceous and micaceous or sometimes calcareous layers alternate with arenaceous ones or thin layers of sandstone. Ripple-marks and rain-drop marks are frequent. A thick series of limestones occurs in the midst of the Bhander shales. It constitutes an important source of lime and is largely worked for that purpose at Sutna.

While the main features of the Upper Vindhyan divisions are so remarkably constant, the minor subdivisions exhibit local differences of the same kind as those noticed in the Lower Vindhyans, only less abrupt. Subsidiary bands occur in the western part of the outcrop which are not found to the east, and *vice versâ.* For instance, the subsidiary limestone, shale and sandstone that accompany the lower diamantiferous conglomerate to the east of Itwa and separate the Jhiri shales from the Kaimur sandstone become extinct in a western direction, so that, at Panna, the Jhiri shales are separated from the Kaimur sandstone merely by the thin layer of diamantiferous conglomerate. Similar instances may also be observed in the Bhander series: for instance, at Sutna and Nagode, the Sirbu shales rest directly upon the Nagode limestone, but at Gonour and further west, subsidiary bands of shale, limestone and sandstone (Lower Bhander sandstone) are intercalated.

The variations in the character of the Kaimur conglomerate are interesting as indicating the proximity of an ancient coast-line close to the present northern border of the Vindhyan formation. It has been noticed by Medlicott that in the outliers and spurs north of the main line of escarpment the pebbles constituting the Kaimur conglomerate are much larger than in the deep valleys, like that of the Ken, that cut back a long way south of the main scarp. This increased coarseness of the conglomerate in a northern direction indicates the proximity of its original limit.

Details concerning the diamantiferous conglomerates will be given in a subsequent chapter.

9.—Lameta, Deccan Trap nd Laterite.

It is only in western Bundelkhand, in the neighbourhood of Baxwaho, that the volcanic rocks of the Deccan Trap period (upper Cretaceous) are extensively

developed. Formerly they far exceeded their present limits and extended eastwards into Baghelkhand as is shown by the occurrence of massive deposits of laterite.

Sometimes these masses of laterite rest upon unaltered basalt of the Deccan Trap. This is frequently the case in the great spread of Deccan Trap that extends west of independent Bundelkhand into the Damoh district. A thin remnant of Deccan Trap occurs beneath the laterite of some hills south-west of Panna, one of which is represented in the section, Pl. 24.

These flat-topped hills, usually of limited extent, whose upper portion consists of laterite are often observed rising above the extensive dip slopes of the great Vindhyan sandstones and resemble in general outline, outliers of the next succeeding Vindhyan division. On closer examination, however, they are found to consist largely and sometimes entirely of laterite. In the latter case, the laterite rests immediately upon the surface of the Vindhyan sandstone. Otherwise there may intervene a sandstone formation belonging to the Lameta system, overlaid by basalt belonging to the Deccan Trap. A typical hill of this sort rises on the surface of the Kaimur dip-slope at Ranipur, four miles north-east of Panna. Others also, situated on the Kaimur sandstone surface, occur further east, in Patarkecher territory. On the Rewa sandstone slope there are a number of conspicuous hills of this kind south-west of Panna. Further east they occur at frequent intervals and acquire considerable importance in the neighbourhood of Semaria and of the falls of the Tons.

The Lameta formation is usually a rather loose sandstone indurated only in its uppermost layers as a contact effect of the overlying Deccan Trap. Besides the remnants of this series mentioned in the neighbourhood of Panna, there is a considerable outcrop near Baxwaho, which is the commencement of an extensive spread of this rock stretching through the Damoh and Saugor districts.

Typical bauxites occur in the laterite of the hills south-west of Panna, but they are too small in extent and too remote from any sources of water-power to be of economic value. It would be worth while ascertaining whether any bauxite occurs in the large spreads of laterite in the neighbourhood of the falls of the Tons.

In addition to these outcrops of massive laterite which have preserved their continuity even since early Tertiary times, remnants of the former covering of Deccan Trap occur scattered all over southern Bundelkhand in the shape of laterite nodules of various size scattered

in varying proportion through the ordinary surface soil or alluvium. When consisting exclusively or nearly so of laterite nodules, these superficial accumulations constitute the lateritic gravels that are principally used for road-making.

10.—Recent or sub-recent formation.

These include alluvium, soil, and some superficial formations such as calcareous tufa.

Except in the northern part of Bundelkhand which includes the southern edge of the Gangetic alluvium, true alluvium exists only in the neighbourhood of river-beds, from whence it passes by insensible gradations into the soils formed directly by the surface decomposition of the rocks. The moment that these decomposition products are transported to some distance by water, they partake of the nature of alluvium, so that it is not always easy to mark out very definitely the difference between alluvium and soil.

The calcareous tufa is deposited by river-water holding in solution a small amount of carbonate of lime which it re-deposits on evaporation. The greatest masses of calcareous tufa are formed where the evaporation of water is greatest, as in the spray of waterfalls. Usually these calcareous tufas are porous or very fine-gained, but sometimes, as at the waterfall near Pathar Chauki, the rock is remarkably crystalline in texture. The limestone, in formations of this kind, is always very pure, and quite free from grit. Lime used for preparing " pán "[1] is manufactured from it.

Calcareous concretions constituting the well-known " kankar " are abundant in certain kinds of soil, particularly in the "black soil" from the Deccan Trap.

CHAPTER II.—ECONOMIC PRODUCTS.

PART I.—DIAMONDS.

SECTION I.—STRATIGRAPHY AND MINERALOGY.

I.—Constitution of the principal diamantiferous conglomerate.

THE Bundelkhand diamonds occur primarily, so far as actual working is concerned, in some of the Vindhyan conglomerates, together with other pebbles derived from the Bundelkhand granite, and the Bijáwar and Son (Lower Vindhyan) series. The

[1] A combination of betel-leaf, areca-nut and other condiments, with lime, much esteemed in India and other Eastern countries.

pebbles from the granitic area consist of vein-quartz derived from the peculiar quartz-reefs that traverse the granite. Those from the Bijáwar consist principally of jasper pebbles, amongst which the red ones are particularly conspicuous. The local name by which these jasper pebbles are known is *sílí*. I heard the name applied to pebbles of grey banded jasper, but omitted to ascertain whether it belongs to the red ones as well. I fancy that these are merely spoken of as "red pebbles." There are numerous pebbles of a green vitreous quartzite derived from the Lower Vindhyans and locally known under the name of *káńsiya* कांसिया or *káńsya* कांस्या. Medlicott was informed that diamonds have been known to occur *inside* such pebbles, but was unable to confirm the statement.[1] I noticed that the workers reject these pebbles without fracturing them when engaged in breaking up the conglomerate and in washing its fragments. There is, however, a notion current amongst them that the presence of numerous pebbles of *káńsya* is a favourable indication of the presence of diamonds. Supposing this to be really the case, the connection may be merely fortuitous. As it is, the workers also stated that the presence of jasper pebbles is a favourable indication. Perhaps it merely comes to this, that the coarser the conglomerate, the more chance there is of discovering large gems, the comparative abundance of larger diamonds in the coarser conglomerates being a consequence of the high specific gravity of the gem, combined with the sorting agency of water. The same explanation should account for the presence of other heavy minerals besides diamonds in the same conglomerate. Fragments of heavy minerals such as galena are frequent and must have been derived from the disintegration of some metalliferous veins, occurring in the same region as the original home of the gem. The absence of any other gems besides diamonds indicates therefore that no other precious stones occur within the area from which the diamonds were originally derived.

In the midst of the conglomerate, there are sometimes cavities of an inch or more stained all round with iron hydrates, and representing probably some mineral rich in iron that has been decomposed and removed by solution. The cavities thus formed often contain well-formed crystals of quartz.

[1] Mem., Geological Survey of India, Volume II, page 71. Manual, 1st ed., pages 84, 92; 2nd ed., page 101.

2.—Stratigraphical position of the principal diamantiferous conglomerate.

In the neighbourhood of Panna the diamantiferous conglomerate rests directly on the uppermost surface of the Kaimur sandstone, at the base of the Rewa shales. In fact, it separates the Kaimur sandstone from the Rewa shales. It is a fairly compact rock containing the pebbles above mentioned in an arenaceous ground-mass The local name for it is *mudda.* The conglomerate is not absolutely continuous. There often occur patches, 2 or 3 feet in extent, where the shale rests directly upon the Kaimur sandstone without any intervention of conglomerate. Its thickness also varies, seldom exceeding two feet. Sometimes the pebbles extend from this arenaceous layer into the shale above. There is then a layer of conglomerate consisting of pebbles in a shaly matrix, overlying the true *mudda* with indurated sandstone matrix. Sometimes this shaly conglomeratic layer does not rest directly upon the indurated arenaceous one, but is separated from it by a layer of shale or of thin-bedded flaggy rather friable sandstone. The latter is observed about one mile east of the Panna mines, at Chúna, where it is sometimes as much as four feet in thickness. These friable shaly conglomerates are known locally under the name of *kakru*, which is a term applied to any loose material containing diamonds, whether it be a Vindhyan shale or a recent alluvial soil.

Further east from Panna, in the neighbourhood of Itwa, the position of the diamantiferous conglomerate differs slightly from that observed near Panna. Instead of resting directly upon the upper surface of the Kaimur sandstone, it is separated from it by some 20 or 25 feet of shale and limestone. A subsidiary band of sandstone, about 20 feet thick, overlies the conglomerate, and underlies the Jhíri shales (see Pl. 23). It probably represents a more developed facies of the subsidiary sandstone separating the *mudda* and *kakru* at the Chúna pits. This interpretation is rendered very probable by the occurrence at Birjpur, 4 miles east of Itwa, of a diamantiferous conglomerate at the upper surface of this subsidiary sandstone, bearing the same relation to the sandstone below and to the Jhírí shales above as the *kakru* at Chúna.

The presence, at different levels, of at least two separate diamantiferous layers, at Chúna and perhaps at Birjpur, disposes of the difficulty referred to by Medlicott as to the stratigraphical position of the diamond-bearing stratum. Under the impression that there existed but one diamond-bearing layer, he was obliged to suppose that the

layer, although continuous, gradually rose through the section between Panna and Birjpur. As a result of this interpretation, Medlicott was led to regard the occurrence of the conglomerate as inevitably restricted within narrow limits, a consequence that does not necessarily follow from the more precise information now available.

In order to reach the diamantiferous conglomerate, pits are sunk through the overlying strata, often to a depth of more than 50 feet. These constitute the workings in which the greatest amount of ingenuity has been displayed, and that have consequently attracted most attention and have been most frequently described, often under the name of "deep workings." Although the deepest workings do belong to this class, depth is not a distinctive characteristic, for near the edges of the outcrop, the depth is, naturally, much less, and may be less than that of some alluvial excavations belonging to quite a different class of workings. It is difficult to find a convenient term that will express concisely this form of workings without using some circumlocution such as "workings of the conglomerate *in situ.*" Though not a very satisfactory term, I shall, for the sake of brevity, call them "direct workings."

All the other workings have been generally grouped together as "superficial workings," a term which is also inappropriate, as some of the pits are nearly 30 feet in depth, and because this classification groups together workings respectively differing in character.

In the neighbourhood of Panna and the country west of it, the occurrence of the diamantiferous conglomerate at the upper surface of the Kaimur sandstone and just beneath the Rewa shales has considerably assisted the extraction of the gems contained in it. As the shales weather more easily than the underlying conglomerate, there is a tendency for the conglomerate to become exposed over considerable areas all along the edge of the shale outcrop. All over these exposed areas it decomposes very slowly into a loose sand or gravel containing the pebbles and the gems, from which the latter can be extracted with a minimum amount of trouble and expense. The moment that the conglomerate has thus been loosened, it is subjected more or less to the transporting agency of water. This may not necessarily be the direct influence of a stream, but the effect of rain is sufficient to spread to a certain distance along the direction of slope, the gravel resulting from the disintegrated conglomerate. Before reaching an

1. Mem., Geological Survey of India, Vol. II, page 70.

actual river-bed where the pebbles become part of the alluvium, they become mixed to a variable extent with superficial soils and lateritic nodules, forming a loose layer of diamantiferous gravels spread over the decomposing outcrop of the original Vindhyan conglomerate, and known locally as *kakru*, though differing essentially from the material known by that name in the Vindhyan shales, with which it has nothing in common save that it is imperfectly indurated and contains diamonds.

The most typical workings of this class are those of Bhowanipur, near Kandla Tal, at Panna. A very large proportion of the older workings were of this class, and it is likely that a considerable proportion of this easily-worked class of deposits has been exhausted. The name "shallow workings" is quite applicable to them, and they will thus be referred to in the following pages. They might also be called "surface workings."

Finally, these loosened materials come more directly under the influence of eroding forces, and become transported into the true alluvial formations. As soon as the elements of the conglomerate have been loosened, they become, as already explained, slightly transported by the agency of rain. Thus, in the superficial diggings above mentioned, where the slope of the surface of the ground is somewhat less than the dip of the stratification, the unweathered Vindhyan conglomerate is sometimes found beneath the detrital *kakru*, showing that the latter is not strictly in the position which it occupied before the pebbles weathered out of their matrix. In the southernmost part of the Bhowanipur field, there may even be a fair thickness of shale between the Vindhyan conglomerate and the diamantiferous *kakru*. This diamond-bearing gravel, re-distributed by the mere effect of rain-wash upon the exposed Vindhyan rock, does not spread, however, to any great distance from the original outcrop. At a short distance further south, the soil no longer contains any pebbles derived from the Vindhyan conglomerate, and no longer, therefore, any diamonds, but merely lateritic nodules, pebbles or boulders of Vindhyan sandstone (mostly from the Upper Rewa sandstone) and flakes of Vindhyan shale.

When the diamantiferous conglomerate becomes subjected not merely to atmospheric disintegration, but also to denudation proper, a different order of things sets in: the sorting power of running water once more comes into play. The pebbles find their way into alluvial deposits of limited extent, restricted to the neighbourhood of river-

courses, but in which the pebbles have become sorted according to size and specific gravity. Some of these alluvial gravels constitute therefore a valuable ground for gems, both on account of their friability and ease of working and on account of the increased relative proportion which the gems sometimes exhibit as a result of the selecting agency that has transported them. Diggings of this nature may be conveniently spoken of as "alluvial workings." They need not necessarily be "superficial" workings, because the diamantiferous gravel is often covered by a considerable thickness of alluvial soil, beneath which the gravel has to be reached through pits that may be as much as thirty feet deep, deeper therefore than many of those which I have classified as "direct workings," and to which the term "deep workings" has generally been restricted in former descriptions.

In these alluvial gravels, the diamonds lie amidst the various kinds of pebbles derived from the original conglomerate, together with nodules of laterite.

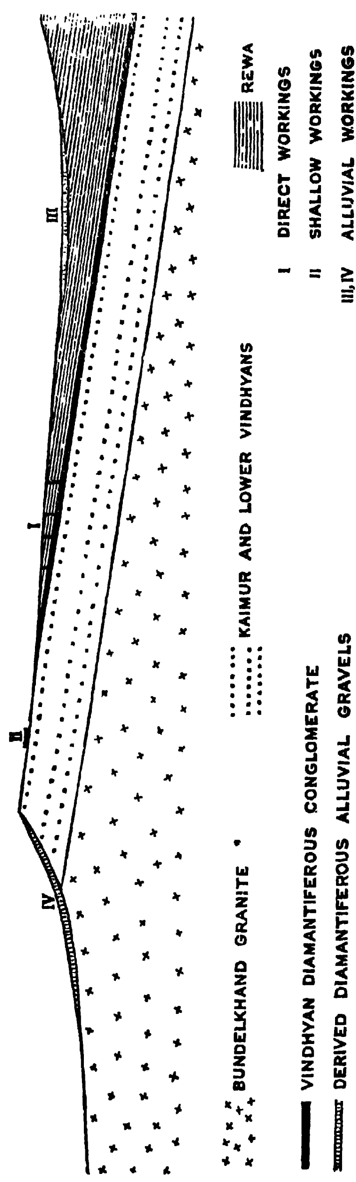


FIG. 1.—*Diagram illustrating the different forms of diamond workings.*

Owing to the position of the outcrop of the diamantiferous conglomerate, along the dip-slope of the Kaimur sandstone, the products of its disintegration may be carried either southwards further down the dip-slope, or northward alo ng the gorges that break through the scrap of the Kaimur. In the former case, just as in the above-

mentioned instance of the re-distributed *kakru*, only in a much greater degree, they lie superposed on a horizon which is newer than the one of the Vindhyan diamantiferous conglomerate from which they were originally derived. A shaft sunk at the same spot would strike the original conglomerate after traversing a certain thickness of shales as at III in the diagram, fig. 1. The workings of Ganeshpur belong to this class. In the second instance, the alluvial conglomerate rests upon rocks older than the diamantiferous conglomerate of the Vindhyans. By sinking a boring, however, deep, the original Vindhyan conglomerate would never be met with (IV in the same diagram). Workings of this type are those of the Bagain valley. The relations between all these different classes of workings are shown on the above diagram.

3.—Second diamantiferous conglomerate.

All the above descriptions refer to the conglomerate situated at the base of the Rewa shales, but there is strong reason to believe that a second one occurs at a higher horizon, but in a very similar manner, overlying the Rewa sandstone, at the base of the Bhander shales. The workings in this particular case belong exclusively to the types II (Sakeriya, Tindini, Durgapur, etc.) and IV (Udesna) of the diagram just referred to. Owing to the absence of any workings corresponding in type with I, I had no opportunity of seeing the actual conglomerate, and it would not be possible to discover it without a much more extensive survey than the present circumstances allowed. In the absence of such observations it might appear possible at first sight that the diamonds should occur in an alluvial formation either modern or of Lameta age, in which they would exist as pebbles derived from the disintegration of the Lower Rewa conglomerate. But the altitude of some of the workings such as those of Sakeriya, which is greater than that of the greatest portion of the outcrop of the Lower Rewa conglomerate and their situation with respect to that outcrop preclude the possibility of such a derivation by means of any kind of drainage compatible with the present geographical conditions or with topographical conditions resembling the present ones, such as we know did exist in Lameta times. Moreover, if the pebbles on the Upper Rewa dip-slope were really derived from the Lower Rewa diamantiferous conglomerate, we should expect to find the diamonds in company with the same pebbles as occur in that older conglomerate. This, however, is not at all the case, for both in the workings of type II on the Upper Rewa dip-slope, and in those of type IV in the gravels of the

rivers draining that area, the large pebbles accompanying the diamonds consist exclusively of vein-quartz. The presence of this vein-quartz is of interest as confirming the conclusion that the gems have originated in the Bundelkhand granite area, but the absence of the jasper and quartzite pebbles, so abundant in the Lower Rewa conglomerate, makes it quite evident that they do not re-present a re-distributed product of that conglomerate. The presence of the quartz pebbles from the Bundelkhand granite area and the absence of the Bijáwar or Lower Vindhyan fragments, indicates that both the latter formations, which were still exposed and subjected to denudation at the commencement of the Rewa period had, at the end of the Rewa time, become completely concealed, or nearly so, by the encroachment of the ocean, and the accumulation of sediments.

There seems to be no doubt, therefore, of the existence of this second conglomerate, and its capabilities are worth testing more thoroughly than has been done so far, as they may considerably extend the area over which the gems can be worked remuneratively.

4.—Possible origin of the diamonds.

All that can be asserted regarding the origin of the diamonds is that they are derived from the Bundelkhand granite area, the disintegration of which furnished the materials that now make up the Vindhyan sandstones. The pebbles of the Lower Rewa conglomerate are derived partly from the quartz reefs of the Bundelkhand granite, partly from the Bijáwars and Lower Vindhyans. Fragments derived from these two sedimentary formations are absent from the Upper Rewa conglomerate which only contains pebbles of vein-quartz. These quartz pebbles derived from the granite area are therefore the essential associates of the diamonds, and the original home of the gem must be one of the rocks of the granitic region, either the granite itself, or its quartz reefs, or the basic dykes.

It is interesting to compare the conditions in Bundelkhand with those of the diamantiferous zone in southern India. In both instances the gems occur in conglomerates of Vindhyan age, in close proximity to a crystalline granitic or gneissic area traversed by innumerable basic dykes of Bijáwar age. In both instances strata of the Bijáwar system (known as Cheyair in southern India), locally intervene between the Vindhyans and crystallines, and it is remarkable that in neither area have any diamonds been met with in the Bijáwar sandstones or conglomerates, though their materials have been derived from the same crystallines as the Vindhyans. It is, of

course, possible that derived diamonds do exist in the Bijáwar conglomerates, but have been overlooked. Yet the absence of diamond workings in that formation and their presence in the Vindhyans in two areas so far apart as Bundelkhand and southern India seems more than a coincidence, suggesting that the diamonds are not older than the Bijáwar, which supposition, coupled with their evident derivation from the crystalline area, points to the basic dykes of Bijáwar age as their possible *nidus*. This is, of course, nothing more than a suggestion, but it may serve to indicate in what direction future investigations might be conducted.

The reputed richness in diamonds of the Panna conglomerate when it contains numerous pebbles of the Lower Vindhyan green quartzite known as *kansya*, if definitely confirmed, does not, of course imply any genetic relation. It would simply signify that the constituents of these portions of the conglomerate were derived from a spot where the particular green quartzite occurred close to an exposure of richly diamantiferous rock, and that both were simultaneously denuded. But the truth of this association within the conglomerate is not well established, and even if it were, our knowledge of the ancient physical conditions of the area is still too imperfect to follow up this clue.

5.—Physical characters of the Panna diamonds.

From a crystallographic point of view, the Panna diamonds belong exclusively to a few modifications of only one form, the "hexakis-octahedron," the most complex form of the cubic system. Some specimens have, at first sight, the general appearance of a simple octahedron and have been described as such, but, on closer inspection, a shallow six-sided pyramid is invariably detected modifying each of the triangular octahedral faces. Amongst the Bundelkhand diamonds, no other crystalline form is ever found in combination with the hexakis-octahedron.

The varieties met with are:—

1. The hexakis-octahedron with all axes equally developed.
2. The same form elongated along an axis of ternary symmetry.
3. The same form unsymmetrically developed, with a curiously tapering termination.[1]
4. Hemihedral crystals approaching the hexakis-tetrahedron.
5. Twins, formed by the interpenetration of two hexakis-tetrahedra.

[1] In Bauer's "Precious stones" there is an excellent representation of this singular form (fig. f, p. 121 of the English edition).

The faces are always regularly curved, but the degree of curvature varies, so that, in some crystals, the six-sided pyramids developed on each face of the octahedron are sufficiently shallow to allow the octahedral outline to remain distinct, while in others they are so convex that the crystals exhibit an almost globular habit.

Out of a total of 220 crystals, I counted: 86 that exhibited the regular shape (1), of which 40 approached closely the octahedron, while the remainder were more globular; 78 showing the form (2), that is, elongated along an axis of ternary symmetry; 5 showing the distorted form (3); 40 hemihedral specimens; and 11 twins.

This gives in percentage:—

(1)	39·09
(2)	35·45
(3)	2·27
(4)	18·18
(5)	5·00

Etch figures are sometimes met with either in the shape of triangular or else of hexagonal pits. They may occur on crystals where the faces of the hexakis-octahedron form very shallow six-sided pyramids upon each face of the fundamental octahedron, but in no single instance have I observed that an actual octahedral face is developed to receive the cavities.

The crystals are remarkably perfect. In spite of the rough treatment to which the conglomerate is subjected when artificially broken up, one seldom observes a broken or cleaved specimen. Out of 241 specimens, I found only 21 cleaved or broken ones, that is less than 9 per cent. The surface of the crystals, in the majority of cases, is beautifully smooth, indicating very little wear since the diamonds were removed from their original matrix. Out of 199 specimens, I counted 136 of which the surface was highly lustrous, 33 in which it was smooth without the same degree of lustre, 25 in which it was frosted, and 5 in which it was rough.

This gives the following percentages:—

Lustrous	68·33
Smooth	16·58
Frosted	12·56
Rough	2·51

When the crystals are examined with a lens, the frosted surface is found to be due to the presence of numerous very shallow triangular etchings all over the crystal faces. The rough crystals when examined in the same manner are found to be irregularly pitted, the pits being usually triangular, but much deeper than when the surface appears merely frosted.

These differences in the appearance of the crystals do not seem to bear any relation to the situation where they occur. Smooth crystals are found in abundance in both the Lower and Upper Rewa conglomerates, and they are just as abundant in the alluvial workings as in the "direct" ones, the short distance over which they have travelled to be transferred from the original Vindhyan conglomerates to the alluvial gravels being evidently too insignificant to affect such a hard mineral. The rough and frosted specimens occur indifferently in all situations.

In colour the majority of the diamonds are either of a brilliant white such as is very seldom met with in South African gems, or are of that still more beautiful blue-white which is quite unknown amongst South African specimens. The outer surface of crystals with a colourless interior is sometimes of a very pale straw-yellow which disappears when the gem is cut, as it only affects a thin film on the outer surface.

The same is the case with some crystals of a very beautiful pale sea-green of exquisite delicacy, which are known as *bánspat* or "bamboo leaves." Such green crystals when cut are perfectly white, but are almost more beautiful in their uncut state. They are very rare. I saw only three amongst 241 diamonds. But greenish crystals of a far less pleasant hue are fairly numerous, and are, commercially, of inferior value because the colour extends more or less through the crystals.

Some of the crystals are of various shades of brown, sometimes very deep, though opaque-black ones have never been observed. These brown crystals are of little value. They are known in the vernacular as *matta*.

Out of 235 crystals, I found: 167 white ones; 40 brown ones, out of which 14 were very pale, 2 very dark, and one nearly black; 14 green ones, of which 3 were of a particularly luminous hue affecting only the outer surface, 10 pale-green or only greenish, and 1 yellowish-green; 7 yellow ones, out of which 3 were pale-yellow, and 2 of a clear honey-yellow; 6 grey ones, out of which 2 were pale-grey or only greyish, and 2 bluish-grey; one stained with hæmatite which had penetrated along cracks through the crystal.

This gives the following percentages:—

White	71·06
Brown	17·02
Green	5·95
Yellow	2·97
Grey	2·55
Stained with hæmatite	·42

The average weight deduced from 240 stones is 0·63 rati or 0·59 carat, the Panna rati weighing 0·9418 carat.[1] Fifty-nine of these stones weighed one rati and above; 181 weighed less than a rati.

There were amongst them:—

	Per cent.
3 stones weighing from 4 to 5 ratis, or	1·25
3 „ „ less than 4 but over 3 ratis, or	1·25
8 „ „ „ „ 3 „ „ 2 „ or	3·33
45 „ „ „ „ 2 „ „ 1 rati or	18·75
32 „ „ „ „ 1 „ „ ½ „ or	13·33
149 „ „ „ „ ½ „ rati, or	62·08

Judging from the number of stones collected during the three first months of 1905, the mines yielding the largest number of gems are the alluvial workings at Ganeshpur, but the stones are of very small size, averaging only 0·27 rati. Those from the alluvial workings of Kaliánpur are still smaller. The alluvial workings that give the best yield, as regards quantity and a good average weight, are those of Itwa.

Of the "direct" workings, those at Sháhidan near Panna are by far the most productive. The workings at Bhowanipur give at present the best return amongst the "surface" or "shallow" workings.

Five working centres yield stones averaging over a rati. These are: Srínagar, Bhowanipur, Chhota Manakpur, Chúnha and Sháhidan. With the exception of Chhota Manakpur, which is alluvial, these are all "direct" or "surface" workings and are all situated within a radius of 3 miles[1] from Panna. The neighbourhood of Panna seems to be therefore, so far as can be judged from these figures, the richest part of the field.

I am unable to say whether the Upper Rewa conglomerate yields gems as large as the Lower Rewa pebble-bed, as I have only seen three small stones derived from that upper conglomerate, two from Sakeriya and one from Maharajpur (Udesna).

6.—Defects.

The majority of crystals are, as above stated, of a beautiful water and lustre, and very seldom clouded or flawed. Their commonest defect, from which very few

[1] In these figures, I have taken the weight of the carat at 205 milligrammes. A crystal purchased at Panna, and stated to weigh 2·15 rati (2 ratis 3 biswas) was found, by means of a chemical balance to weigh 0·4151 grammes. This would give the Panna rati a value of 193·07 milligrammes, or 0·9418 carat. I was told at Panna that the ratio of the rati to the carat is 10/11, the carat weighing, according to this information, 22 biswa or 1·1 rati, which would give the rati a weight of 186·36 grammes or 0·909 carat.

are entirely free consists in the presence of "spots," which are black opaque inclusions of jagged outline. Owing to this defect a large number of the stones are unfit for the European market, though they are saleable in India.

Out of 58 stones weighing over a rati, I saw only 24, less than half therefore, which were free from inclusions, or in which these could only be detected with a lens and were of too small a size to detract much from the value of the stone.

SECTION II.—METHODS OF EXTRACTION.

I.—Classification of workings.

The most detailed accounts that have been published concerning the mining operations in the Panna diamond zone are those of various travellers in the early part of the nineteenth century. The descriptions of Franklin[1] and of Jacquemont[2] are particularly accurate, and have been partly reproduced in the works of Medlicott[3] and Ball[4]. The latter author's account is largely based upon some observations of Medlicott and of Hackett, neither of whom, however, witnessed the extraction of the ore, as they had left the field before the miners had reached the diamond bearing layer. When I reached Panna towards the end of March 1905, the diamond-bearing layer had already been uncovered in some of the pits. The methods of extraction that I witnessed are evidently just the same as those observed by Franklin and by Jacquemont some 80 years ago, and even at an earlier date by some of their predecessors; but in the light of the geological knowledge since acquired it may be of interest to give a detailed account of my observations, especially as I had the opportunity of watching the operations throughout all their principal stages.

In order to describe the present methods of working, and thus gain some idea of the possibility of improving them, it will be convenient to make use of the classification outlined in the previous pages, that is "direct" workings which seek the diamantiferous conglomerate beneath its covering of shales; "shallow" or "surface" workings upon the conglomerate either exposed at the surface through removal,

[1] On the Diamond Mines of Panna in Bundelkhand. Asiatic Researches, Vol. XVIII, Part I, p. 100 (1829).

[2] Voyage dans l'Inde pendant les années 1828 à 1832, Vol. I, p. 399 (1841.)

[3] Mem., Geol. Surv. of India, Vol. II, p. 65 (1860).

[4] Economic Geology, p. 39 (1881).

by denudation, of the shales, or concealed under a small thickness of alluvium; lastly, "alluvial" workings.

The following are the principal localities that have yielded diamonds, the arrangement of the lists being in each case from west to east:—

I.—Workings connected with the older conglomerate.

Direct Workings.

Sháhidan	Panna State.
Chúnha	Do.
Kaliánpur (abandoned) . . .	Do.
Khameria	Charkari State.

Shallow (Surface) Workings.

Maraia	Panna State.
Bandi	Do.
Bhowanipur	Do.
Harduapur	Do.
Srinagar	Do.
Ogra	Do.
Manakpur	Do.
Simra	Bijáwar State.
Día	Chobpur State.
Majgawan	Patarkechar State.

Alluvial Workings.

Majgama	Panna State.
Old Panna	Do.
Chhota Manakpur . . .	Do.
Kaliánpur	Do.
Ganeshpur	Do.
Radhapur	Do.
Hardua	Do.
Ranipur	Charkari State.
Patti	Do.
Bajaria	Do.
Babupur	Panna State,
Itwa	Do.
Birjpur (partly "shallow") . .	Do.
Seha, etc.	Chobpur State.
Jhanda	Do.
Banari	Patarkechar State,

I have not ascertained the exact nature of the following workings: Sirswa, Maharajpur and Gehera near Itwa; Bhim Pahar near Birjpur; Bardhai near the Bisraumganj road.

II.—Workings connected with newer conglomerate

Shallow Workings.

Sakeriya	Panna State.
Tindini	Do.
Mohra	Do.
Durgapur	Do.
Singhpur	Do.
Jhanda	Kothi State.

Alluvial Workings.

Udesna	Panna State.
Naigawa	Kothi State.

We shall examine first, the "direct workings," that is, the ones formerly described as "deep workings," secondly, the "shallow workings," thirdly, the alluvial diggings.

2.—Direct workings; extraction of the ore.

It is the workings for extracting the *mudda* from beneath a covering of Lower Rewa shales that give occasion for the most complex operations. Cylindrical pits are excavated varying in width from 18 to 35 feet. The deeper are also the narrower, the reason being to avoid excessive labour. It is advantageous, according to the method pursued, to make the pit as wide as possible, but on account of the limited period during which work is practicable, if the excavation were started with too wide a diameter at those places where the conglomerate lies at a great depth, there would be no chance of reaching a sufficient depth during the short season when this work can be carried on. The instruments used are picks and shovels. The excavated materials are rapidly removed in small baskets which the women and children pass from hand to hand. They are dumped down in the immediate neighbourhood of the pit, and these accumulated heaps of débris and rubbish cause a vast amount of confusion which constantly increases. So long as the depth of the pit remains moderate, the descent is provided for by reserving steps around its walls, in the same manner as is usual in excavating a deep well for water. When the depth reaches some twenty feet, the approach to the floor of the pit is by means of an incline, the lower part of which, if the depth is

greater still, is usually tunnelled. The picks and shovels above-mentioned are sufficient for excavating the superficial soil and boulders, often consisting of the rubbish heaps of previous excavations, and the soft shales and interbedded thin sandstone layers. They also suffice for extracting the pebbly bands with shaly matrix which either overlie directly the *mudda*, or are separated from it by means of a few layers of shaly sandstone flags, and are also sufficient to extract the latter as well. But the conglomerate itself which has a hard sandstone matrix cannot be excavated by this means. To facilitate its extraction, recourse is had to the following method: the surface of the conglomerate is cleared and a wood fire lighted upon its surface, which is allowed to burn for several hours. The effect of thus violently heating the surface of the stone is to render it somewhat friable and to develop cracks parallel with the bedding. Thus treated, the upper part of the conglomeratic layer becomes fissile and can be detached in large irregular horizontal slabs. When the fire has burnt out and these slabs have sufficiently cooled down to be handled, they are lifted by means of the same picks as were used for excavating the pit. When these do not suffice for detaching the slabs, recourse is had to pointed chisels used as wedges, and hit with common-shaped heavy-headed hammers. Each piece, as it is lifted out, is carefully examined to see if it does not show any conspicuous diamond, and is then consigned to a heap of *mudda* fragments, for further treatment to be described hereafter. It often happens that the effect of the fire is only sufficient to scale off a small thickness, perhaps 2 or 3 inches of the *mudda*. As the conglomerate often reaches a foot or more in thickness, this is but a fraction of its total amount, and, to detach the remainder, the same operation is repeated as many times as is necessary to reach the underlying unproductive sandstone. When the *mudda* has thus been entirely lifted off the floor of the pit, radiating galleries are driven to uncover it from below the mass of shales surrounding the space that has been opened out. The waste materials from these galleries are not carried out of the mine, but heaped up on the floor of the pit, from which the valuable conglomerate has already been removed. Fires are lighted in these galleries and the conglomerate flaked off in the same manner as in the circular open area of the pit. When the diamond ore has been extracted from these galleries, they are filled in with stone slabs and rubble so as to support the roof and allow other galleries to be driven

by their side. By this means, an area far more extensive than that directly uncovered by the pit is made to yield its material. It is, in fact, a rudimentary form of mining.

Wherever the conglomerate lies at 20 feet from the surface or more, it is situated below the saturated water-level of the soil, except late in the dry season. This is why the excavation of many of the pits is not commenced before March, and it is in the brief interval between this and the rains that the remunerative material can be extracted. According to the information kindly furnished by the Panna Darbar, the work in the Sháhidan mines, all of which belong to the "direct" type, does not commence till October. In the case of one particular mine, that of Lalla Ram Sukh, the work was commenced on the 16th of November. When I saw this mine at the end of March, the excavation of the pit was already complete and most of the conglomerate had been removed from the floor. Lateral galleries had already been commenced. In many other instances, the excavation at that same period had been hardly commenced, and it is evident that the work could not have begun before the beginning of March or the end of February at the earliest. The depth of the water-level and that of the conglomerate, both of which are known to the miners from previous experience, no doubt settles the date at which it is desirable to commence work at each particular spot. In order to gain time, it is customary to commence excavating the pits before the level of saturation has sunk below that of the diamond-bearing conglomerate, and a "persian wheel," worked by bullocks, or if the percolation is very slow, merely turned by hand, is used to drain the surplus water. This method allows the removal of the shaly conglomerate layer or *kakru* even if it is still below the water-level. The well-known illustrations of the late Mr. Schaumburg depict the mines at this particular stage.[1]

For the extraction of the *mudda*, the water-level must eventually sink sufficiently below its surface in order to make use of the ordinary method of heating the surface with a wood fire. In many of these pits the shales exhibit curious V-shaped folds which have been described by Jacquemont and by Medlicott, the exact origin of which it is difficult to account for.

At Sháhidan, I understand that the shale is known to the workmen as *malwa*; but in other localities this term is applied to the lateritic gravel.

[1] In "L'Inde des Rajahs" by Rousselet, and in Ball's Ecomomic Manual.

Even in the deepest of these "mines," the shales are sufficiently compact to stand without any artificial support in the vertical walls of the pit so long as work continues, that is, until the rains set in. But as soon as they become soaked by rain-water, they begin to collapse and the rubbish accumulated all round the pit also soon falls in and obliterates the excavation. A second pit may be sunk the following year by the side of the first one and the material excavated from it thrown into the half-filled former pit, thus completing its obliteration. In the Sháhidan field, this has been so often repeated, and the work has been carried on in such an irregular manner, that it has now become impossible to tell for certain if any particular spot has previously been worked. Wherever one may attempt excavations in the Sháhidan field, the ground is sure to consist, in part at least, of artificially disturbed material.

I understand that the workers call this made-ground *purão.* The undisturbed material that has never been excavated is called *jamára.*

As an example of these "direct" workings, the following section has been measured in Lalla Ram Sukh's mine, already referred to

	Thickness.	Total depth from surface.
Soil intermixed with numerous large rounded boulders of sandstone, to a certain extent artificially disturbed and redistributed by previous mining operations . . .	11′	11′
Broken up disturbed shale	1′ 6″	12′ 6″
Shale striped red and green, soft and friable .	11′ 11″	24′ 5″
Friable green or mottled sandstone . .	0′ 7″	25′
Shale striped red and green	3′	28′
Kakru, mudda and Kaimur sandstone.		

The following particulars were kindly communicated by the Panna Darbar regarding this mine:

"The excavation of the mine commenced from 16th November 1904.

"2. Ten men and fifteen women were employed for the excavation up to February 1905. Afterwards the number of labourers was reduced to eight men and eight women, and they will work up to June 1905 so far as excavation is concerned.

"The monthly wage for each man is R6 and that for each woman is R3.

"3. The same number of labourers, that is, eight men and eight

women, will be employed for the surface operation of breaking the ore, washing it and searching for diamonds till the end of the rainy season, or till such time as the searching is completed.

"4. The quantity of fuel required for breaking the hard *mudda* is about 4 cart-loads. This varies greatly in different mines, as it depends chiefly upon the nature of the *mudda* to be broken up.

"5. Total cost of tools (pick-axes, spades, hammers, baskets, etc.) R30 required for the working of a mine like the one referred to above; these articles are provided by the man who owns the mine, and not by the labourers."

The *mudda* in this mine was seldom more than 2 to 3 inches in thickness and was wanting over some portions of the area. It invariably passed upwards into a layer of *kakru* with shaly matrix.

When I first saw the pit on the 24th March, the conglomerate had not yet been entirely removed from its floor. Some short galleries had just been started. These had been extended to some considerable distance about a month later, and the rubbish from these excavations had been heaped on to the floor in the middle of the mine.

If we go further north than the pit from which the above section is described, the *mudda* is found at a much smaller depth owing to the southerly dip of the strata that causes the conglomerate itself to outcrop a little further north, the actual outcrop being, however, seldom visible otherwise than in artificial excavations owing to the great thickness of alluvial soil that occupies the plain extending between the Kaimur dip-slope and the Rewa scarp. In the pits that I examined in this northern part of the field, the total depth down to the *mudda* was only 15 feet, of which the upper 6 feet consisted of undisturbed alluvial buff-coloured soil. This part of the field did not seem to have been previously disturbed and contained none of the artificial ground known as *purâo*. In these pits the conglomerate is much coarser than in the one first described. It is a foot or more in thickness and contains boulders of *kansya* of as much as one foot. It is in one of these pits that I was shown the Bijâwar-like jasper which is known as *síli*. Pebbles of the typical red jasper are found in all exposures of the *mudda*. Lumps of galena and the ferruginous-looking cavities lined with quartz crystals described in a previous paragraph are frequently found in this part of the conglomerate.

The diagrams, Pl. 25 and 26, represent the section and plan of a mine situated in another part of the Sháhidan field, where the

water-level, at the time of my visit, had not yet sunk below the horizon of the diamantiferous conglomerate.

The galleries driven from the floor of the mine are always very short and tortuous, scarcely more than 10 feet in length, and probably, in the aggregate, do not do more than double the area directly uncovered by the pit. Therein lies the main defect of the present system of working, the sinking of so many deep pits, every year, being quite out of proportion with the result obtained. Except where the conglomerate comes very near the surface and is overlaid directly by alluvium, or else by shale which has been broken up and decomposed owing to its proximity to the surface, the shale layers, as seen in the mines just described, and in many others, are quite compact enough to form a sound roof to the galleries, and the conglomerate could certainly be extracted by systematic mining, while the drainage of the mines by means of adequate pumps, would allow the work of extraction to proceed all the year round.

At the locality called Chúna or Chúnha which is situated east by north of Sháhidan, the galleries are somewhat more important than at Sháhidan. I saw one which was directly reached by an incline, without the previous sinking of a shaft, and was 6 feet in breadth, and the same in height. The shales as seen in this gallery are more compact than at Sháhidan. Another broad gallery, perhaps 60 feet in length or more, started from the first one and extended up to a shaft previously sunk. It is in these works that I observed that the *mudda* and *kakru* are separated by a variable thickness of sandstone layers, forming irregularly bedded slabs. This flaggy sandstone is locally known as *chaoni* and its aggregate thickness may reach 4 feet.

In one of these pits the *kakru* was 6 inches thick and very friable. Beneath it were 2 or 3 feet of semi-shaly, semi-sandy *chaoni*, then the *mudda*. The *mudda* is well exposed in another mine close by. It is the one just mentioned, which has an unusually extensive development of underground galleries. There the *mudda* is over a foot in thickness, the *chaoni* much reduced. The pit just mentioned is about 22 feet deep, of which more than half is very "kankary" alluvium full of nodules of carbonate of lime, which I was given to understand to be the origin of the name "Chúna."

Not more than 600 feet from the Chúna pits, in a northerly or north-easterly direction, the Kaimur sandstone is exposed in the river-beds, the overlying shales and, to a great extent, the *mudda*

having been entirely removed by denudation. Along its continuation eastwards of Chúna, the outcrop has been extensively burrowed for about another 900 feet. From there, however, up to Kaliánpur, there is no indication of any more working, at least not along the line I traversed. About half a mile west of Kaliánpur, flaggy sandstone layers, belonging to the shale group are found in a river-bed. There are no indications of working, though the *mudda* no doubt exists at a moderate depth.

Formerly the *mudda* was reached at Kaliánpur in pits of considerable depth, up to 60 feet. These workings have long since been stopped, and the only ones carried on at present in that locality are alluvial.

The mines in the neighbourhood of Itwa in which the diamantiferous layer was obtained from the roof instead of from the floor of the galleries, and which have been described by Medlicott and Ball, are no longer worked at the present day.

3.—Surface operations.

In order to extract the gems from these conglomerates whether friable *kakru* or compact *mudda*, they have to be broken up so as to separate the pebbles that constitute them, and among which the diamonds are scattered.

The fragments of the shaly *kakru* are easily disintegrated by lixiviation in water. In this way the constituent pebbles are loosened from their matrix, but still remain embedded in the thick mud which this clayey matrix forms by the admixture of water. The gravel has therefore to be washed before being searched for diamonds. For the purpose of washing the gravel, it is customary to excavate, in the stiff alluvial clay, that occupies the surface of the ground in most of the diamond fields, groups of pits consisting of two rectangular ones, about 6′ × 4′ × 2′ and one circular one, about two feet in diameter and two in depth. The alluvial clay, once it is wet, is usually sufficiently impervious to hold the water needed in the washing operations, which are often conducted in pits thus simply excavated without any further preparation; but at other times, the pits are lined with flags of Vindhyan sandstone, so as to avoid an undue admixture of alluvial clay during the washing of the *kakru*. The rectangular pits are half-filled with the broken up *kakru* which is completely immersed in water, the disintegrated shaly matrix thus assuming the consistence of mud. One man stands in each of the pits, and churns the mass, so that the particles of mud should be completely loosened from the pebbles. When this has been done sufficiently, the resulting

gravel is lifted out in baskets, which are repeatedly dipped in the circular pit so as to wash away the mud from the sand grains and pebbles. Clean water from an earthenware vessel is finally poured over the baskets to remove the last traces of mud. The contents of the baskets are then evenly spread over a smooth and clear area where, after drying, they are carefully turned over and over by hand and searched for diamonds. For searching, the spread out material is gradually scraped together in a heap by the palm of the hand being at the same time diligently watched for any gem that may be uncovered in so doing. The heap thus gathered together is again spread out, and the operation repeated many times.

As to the *mudda*, before it can be similarly treated, it has to be broken up into small fragments. This is done in circular pits about 6 feet in diameter and 3 feet in depth. The conglomerate fragments are piled up in the pits and are repeatedly broken by the blows of sledge hammers from two men standing in the pits. The sledge hammers are of the ordinary shape, and it is to be noticed that the broad sides of the hammer head appear to be much more largely made use of than the narrow ends. The process is continued until the fragments are sufficiently small to be treated in the same way as *kakru*. The depth of the circular pits prevents any fragments from being lost by flying away from the breaking floors. It is remarkable that in spite of this rough treatment, the diamonds seldom appear to be broken. Such an accident will probably only happen in the very rare event of the hammer actually hitting a crystal. In most cases the effect of the blows must be merely to dislodge the diamonds from their matrix.

At no stage of the operation is sifting of any sort had recourse to. Only the conspicuous large pebbles or fragments of *kansya* or jasper, or fragments of unproductive Vindhyan sandstone are thrown aside when they happen to be noticed. One would think that some inexpensive form of sifting would make the search easier. The unequal size of the grains spread out on the searching floors must be an obstacle to this operation.

It is to be noticed that these surface operations are not confined to the period of excavation. Indeed it is after the rains have commenced that the heaps of conglomerate extracted from the mine during the dry season are most actively treated in this way, first, because the abundance of water greatly facilitates the progress of this work, and also because during the dry season every available

hand is turned to the work of excavating. When the work of excavating is finished, the same labourers turn their attention to the surface operations.

4.—Shallow workings.

I have defined as "shallow workings," or "surface workings," those that seek the more or less disintegrated surface of the diamantiferous conglomerate where it crops out from beneath the Rewa shales.

In these shallow workings the details of the process are essentially the same as those just described except that the excavating operations are reduced to a minimum. There is no need for heating the surface of the *mudda* which is rarely present in a compact and undisintegrated form, and even then has been to some extent decomposed and softened by surface water.

The following observations were made at some of these "surface" or "shallow" workings.

Bhowanipur.—At the time of my visit, the most actively worked amongst these shallow diggings were those at Bhowanipur, near a group of two tanks known as Kumla Tál, immediately west of Panna. The position of the *mudda* is exactly the same as at Sháhidan, that is resting immediately on the upper surface of the Kaimur sandstone, but the shale is not seen in the excavations because the diggings are at the very edge of the outcrop of the *mudda* from which the overlying shales have been entirely removed by denudation. Upon the undisintegrated *mudda* there rests immediately the decomposed material from the weathering of neighbouring portions of the same conglomerate situated a little further up the dip-slope, and spread by rain-wash, as explained in a previous paragraph. This redistributed loose material is called *kakru*. In some other pits this *kakru* consisting of the broken up weathered remains of the *mudda* rests directly upon ordinary Upper Kaimur, the original *mudda* having been entirely disintegrated. This *kakru* consists largely of small pebbles of laterite, together with broken fragments of shale and sandstone and pebbles from the original *mudda*. It is usually overlain by a certain thickness of alluvium. It is carefully excavated even from amongst the interstices between the weathered portions of the surface of the Upper Kaimur sandstone and searched for diamonds.

Harduapur.—The workings at Harduapur, a little further east along the outcrop (between Sháhidan and Bhowanipur) resemble those of Bhowanipur, only there usually still exist a few layers of shale on the top of the *mudda*. The small pits are only about 6 feet deep with

variable amounts of soil and of shale resting on the *mudda.* The superficial layers full of laterite are not searched for diamonds. The only portion that is searched is the broken material resting on the *mudda* either directly or with the intervention of a small thickness of shales.

Srínagar.—The workings to the north and north-east of Harduapur are known as Srínagar. They form the continuation of the superficial outcrop beyond Harduapur. Here, at Srínagar, the *mudda* has been entirely removed by denudation. More than 8 feet of detrital soil rests upon the denuded surface of the Kaimur sandstone. Not only does the lowest layer, resting directly upon the sandstone surface, constitute a productive *kakru*, but there may be another productive layer situated a little higher up.

The section, Fig. 2, represents a pit where the working had just been stopped at the time of my visit (these workings being excavated chiefly during the rains).

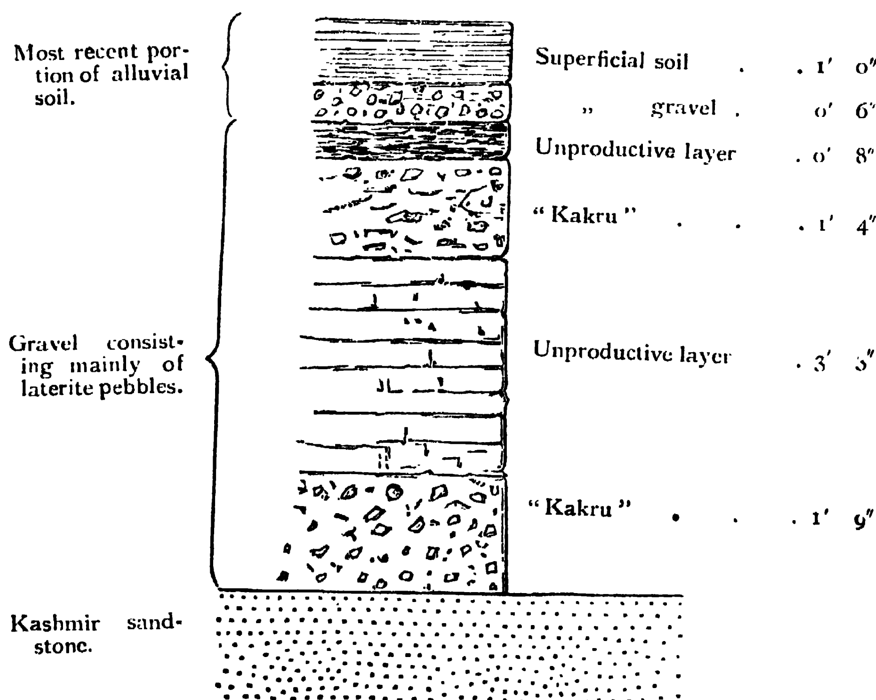


FIG. 2.—*Section of a pit at Srínagar.*

The section consists of the following strata :—

		Thickness of layer.	Total depth.
Most recent alluvial soil	Superficial soil	1′ 0″	1′ 0″
	" gravel	0′ 6″	1′ 6″
Gravel consisting mainly of laterite pebbles.	Unproductive layer	0′ 8″	2′ 2″
	Kakru	1′ 4″	3′ 6″
	Unproductive layer	3′ 3″	6′ 9″
	Kakru	1′ 9″	8′ 6″
Kaimur sandstone.			

The productive layers contain, in addition to the little laterite grains and pebbles, a certain number of fragments of shale or shaly sandstone.

Ogra.—The workings called "Ogra" are situated north of the Sháhidan mines. They are along the continuation of the Srínagar outcrop, further west The *mudda* is sometimes seen *in situ*, but without any remnants of shale. The ground appears to have been turned up over and over again, and the locality is probably to a great extent exhausted.

On account of the ease with which operations are conducted in workings of this class, they are probably largely exhausted. Yet a number of localities probably remain where, through ignorance of the geological lie of the stratum, the outcrop has not been detected and the diamantiferous layer remains intact under an insignificant covering of alluvial soil.

On account of the weathered condition of the *mudda*, there is no need for the troublesome process of calcining its surface before extraction, even when it has escaped complete disintegration and reduction to gravel. At least there is no need for this operation at Bhowanipur. I omitted to enquire whether such a process is ever carried out at Harduapur or Ogra, where the compact conglomerate also remains *in situ*. In all other cases, the diamond ore is always a loose detrital gravel, a *kakru*. After extraction, this is treated in exactly the same manner as has been described for the *kakru* occurring within the lower Rewa shales. Owing to the shallowness of the workings, and the ease of reaching the productive layer, the parts of the field occupied by "shallow workings," present even a more confused appearance, if possible, than that in which the conglomerate is reached by the deeper "direct" workings. Unlike the latter workings, in which the presence of water renders work impossible during the rains, the

superficial detrital deposits are worked mostly during the wet season when water is everywhere available for washing the diamantiferous gravel.

5.—Alluvial workings.

It has already been explained that through the continuation of the processes connected with denudation, the gravel weathered out of the conglomerate ultimately finds its way into true alluvial deposits, which can be worked with success along the banks and in the very beds of existing streams.

I got a clear view of these alluvial deposits at the following localities :—

Kaliánpur.
Ganeshpur.
Rádhápur.
Chhota Manakpur.
Itwa.

Kaliánpur.—The Kaliánpur workings are near the confluence of a small stream coming from Kaliánpur village, with the Ranj river. The constitution of the alluvium in the shallow pits is as follows :—

	Thickness of layer.	Total thickness.
Soil with one intermediate band of laterite and shaly pebbles	1′ 4″	1′ 4″
Laterite pebbles	0′ 8″	2′ 0″
Soil	1′ 10″	3′ 10″
Kakru	2′ 2″	6′ 0″
Broken shale.		

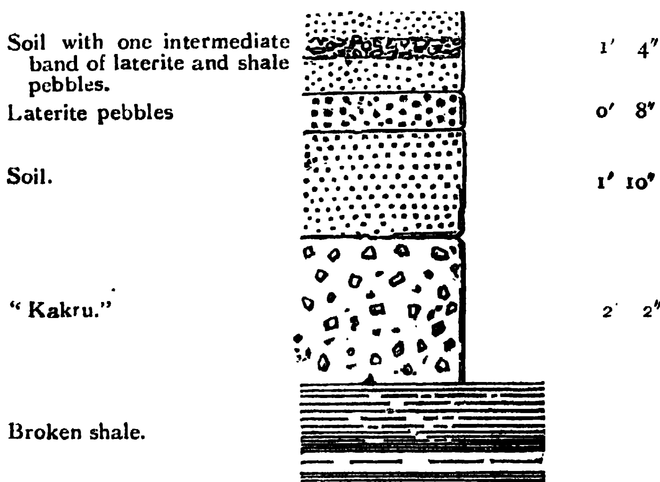


FIG. 3.—*Section of a pit at Kaliánpur.*

The section, Fig. 3, represents the constitution of the alluvium in the shallow pits. The *kakru* consists of fragments of shale and rounded sandstone pebbles embedded in mud.

Ganeshpur.—The Ganeshpur workings are along the left bank of the Ranj river, a little lower down than the Kaliánpur ones. The river at this place flows between deep alluvial banks, so that the pits, although entirely through alluvium, may, nevertheless, be over 12 feet depth. (See section, Fig. 4.)

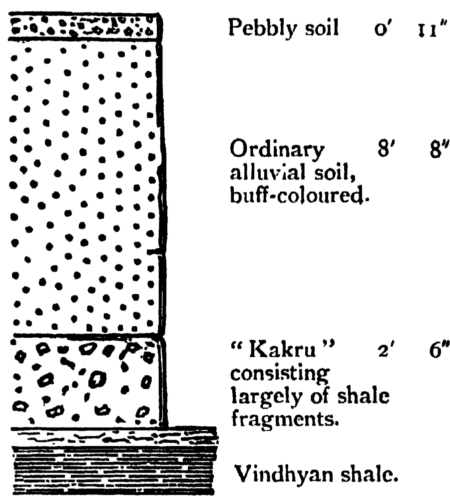


FIG. 4—*Section of a pit at Ganeshpur.*

The thickness of the layers is as follows:—

	Thickness of layer.		Total depth.	
Pebbly soil	0'	11"	0'	11"
Ordinary alluvial soil, buff coloured . .	8'	8"	9'	7"
Kakru consisting largely of shale fragments	2'	6	12'	1"
Vindhyan shale.				

Rádhápur.—The workings on the right bank of the Ranj river, opposite Ganeshpur, are known as Rádhápur and resemble those of Ganeshpur.

Chhota Manakpur.—Workings of the same nature are found at Chhota Manakpur, west of the Bisramganj (Ajaigarh) road, along streams draining the plateau which, on the map, is shown as carrying a village called Kodaia, but which, I understand, is now known as Bara

Manakpur. A large area occupied by the weathered remnants of the *mudda*, and similar to such areas as Srínagar and Ogra, is worked during six months (beginning with the rains) all about Bara Manakpur. It appears to be, now, largely exhausted. The redistributed material from these weathered surfaces forms again a *kakru* layer in the alluvium of the rivers draining it, resting, however, on denuded Kaimur sandstone, not on Rewa shales.

Bandi.—Conditions similar to those of Bara Manakpur and Chhota Manakpur also exist at Bandi, where the workings only take place during the rains and are now languishing.

Hírapur.—Alluvial workings similar to those of Ganeshpur and Rádhápur, etc., were formerly carried on in the Kuria river near Hírapur, W. S. W. of Panna, but have now been abandoned.

Old Panna.—The workings in the valley of the Kuria river near Old Panna are also alluvial, but are situated on a horizon lower than that of the original *mudda*.

Itwa.—Formerly there were "direct" workings at Itwa, which have been described by Medlicott and by Ball. The only workings that are now actively carried on in that locality are alluvial. Those that I saw are along the river that flows past Maraia into Itwa, and are situated above Maraia. The depth of alluvial soil is considerable. The first pit that I saw is 25½ feet deep. Of this amount, 18 feet are above the water-level, the remaining 7½ feet under water. Below this, again, comes one foot of *kakru*, the diamond-bearing gravel mixed with lateritic pebbles. Another pit 20 feet deep had just reached the water-level, and required another 10½ feet before reaching the diamantiferous gravel, making it much deeper therefore than many of the "deep" mines at Sháhidan.[1]

There is no mechanical appliance for lifting out the water from these pits. It is removed simply by earthenware vessels handed up from below. In one pit I saw a tunnel leading from the floor of the pit and communicating with a small inclined channel to drain the pit into the river-bed close by.

[1] I was given to understand that the laterite pebbles associated with this alluvial *kakru* are known as *chila*. Franklin and Jacquemont refer the word *chila* not to a particular kind of rock, but to superficial workings in general. It may be that the word properly belongs to the laterite pebbles and is consequently applied to the workings containing such pebbles, all of which workings are more or less of the alluvial class.

6.—Workings connected with the Upper Rewa conglomerate.

These workings are situated principally on the dip-slope of the Upper Rewa sandstone, and extend from Sakeriya near Panna to Jhanda and Naogaon near Kothi. All these belong to the same type as the "shallow" workings on the Kaimur dip-slope. As there was no work in progress at the time of my visit, I did not ee any exposure of the undisturbed conglomerate. The excavations are carried on only during the rainy season. I only saw one pit, which was specially excavated at Sakeriya, in order to give me some idea of the formations met with.[1]

The section observed was as follows (Fig. 5):—

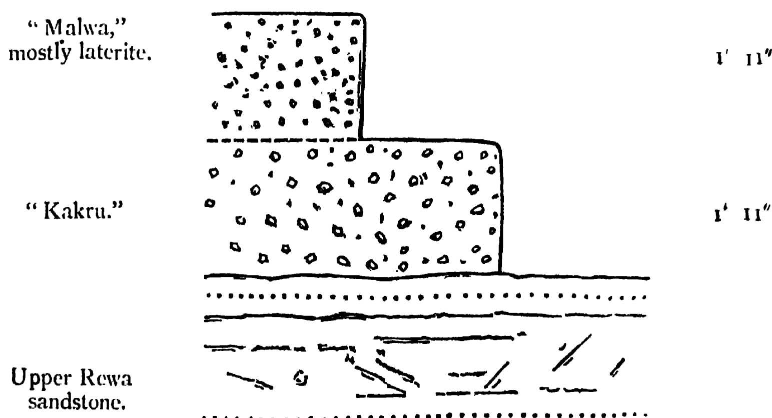


FIG. 5—*Section of a pit at Sakeriya.*

	Thickness of layer.	Total depth.
Malwa, mostly laterite pebbles	1' 11"	1' 11'
Kakru	1' 11"	3' 10'
Upper Rewa sandstone.		

[1] The workings referred to by Medlicott (Mem. G. S. I., Vol. II, p. 73) are not situated at Sakeriya itself, but north of that village, in the gorge of a river which cuts across the Rewa scarp and flows from Sakeriya to Udesna. The pits described by Medlicott are situated about half-way between these two localities and are alluvial workings, the gems being derived from the disintegration of the Upper Rewa conglomerate exposed near Sakeriya. The workings at Sakeriya proper are those referred to by Medlicott in the following words: "Above these deep pits which are never far from the stream, and well up on the slope of the Rewah sandstone, are *chila* diggings in the surface lateritic gravel."

The *kakru* consists of soil, fragments of Vindhyan sandstone, and pebbles of vein-quartz.

On the opposite side of the same pit, the *kakru* is not overlaid immediately by lateritic soil, or *malwa*, but there intervenes a curious accumulation of irregularly bedded, friable, bright-coloured sandstone known as *chánchar* चांचर. Many of the boulders of weathered Vindhyan sandstone, boulders which perhaps existed as detached blocks at a period as old as the Deccan Trap, have now become quite friable, and, in the disturbed and ill-exposed walls of the small pit, one cannot entirely escape the suspicion that this friable sandstone may be simply accumulated fragmentary slabs of Vindhyan sandstone that has become friable. At the same time, the bedding appears too distinct to be in all certainty a mere accumulation of Vindhyan fragments, and one is led to the conclusion that it is either a recent semi-indurated alluvial sand, or, possibly, a remnant of the Lameta group, in which latter case the underlying *kakru* would necessarily be partly of Lameta age, which attribution is by no means improbable, since the geographic conditions in those days were very similar to those prevailing at present. (See section, Fig. 6.)

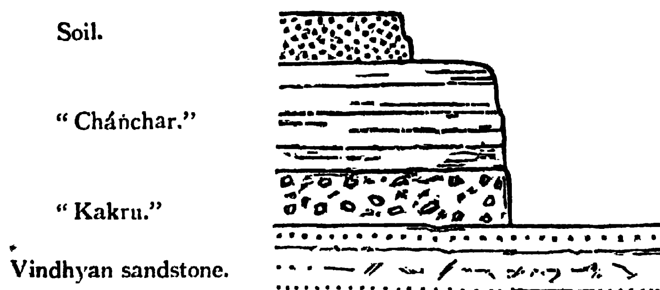


FIG. 6—*Another part of the pit represented in Fig. 5.*

7.—Disposal.

The diamonds are sold by auction, at Panna, at the beginning of each month. In the case of stones of less than 6 ratis in weight, the owner obtains three quarters of the price and the State one quarter. After the highest bid, the original owner has the option of buying the stone at that figure. Stones of 6 ratis and over are the property of the State. The finder in this case gets one quarter of the value.

8.—Suggestions regarding the possibility of increasing the present outturn of the mines.

It follows from the above account that, in order to obtain the diamond-bearing conglomerates or gravels, the entire column of strata overlying them is removed. This is equivalent to quarrying away the entire formation, sometimes as much as 60 feet thick, from above the diamantiferous layer, though the actual productive layer thus laid bare is scarcely ever more than 2 feet thick and often only a few inches. Moreover, owing to the want of care in the method pursued, it may be safely asserted that the material is quarried twice over, as every mine has to be started through the accumulated rubbish of previous excavations.

The method is probably the only practicable one in the case of the alluvial deposits, and, with respect to the "shallow workings," it is certainly the most advantageous one, provided that the work be systematised, and not carried on at hap-hazard as it is at present. But with regard to the deep workings of the "direct" type, which must eventually become the most extensive ones to the final exclusion of the two other classes, which will be the first to attain exhaustion, the waste of labour in removing material to a depth of close upon 60 feet must be excessive. That the work should be remunerative with such a system, or rather want of system, seems a fairly conclusive indication that the present outturn and profit could be bettered by a more economic method.

The constancy of the Vindhyan conglomerate over a considerable area is one of the favourable features of the case. The present workings are situated at small distances from one another all along the outcrop and have probably originated at each locality from chance discoveries, the workings having spread until the flooding of the pits or other material difficulties prevented them from advancing any further in any particular direction. In some instances where attempts have been made to reach the conglomerate through pits situated at some distance from any workings, the work has had to be discontinued before reaching a sufficient depth, owing to the influx of water. A few inexpensive trials will suffice to verify the regularity of the diamond-bearing capacity of the conglomerate.

At all events, there are some places, such as Sháhidan, Bhowanipur, Kaliánpur, where the diamantiferous bed certainly forms a regular stratum, and where it could be mined like any other material occurring in regular layers, such as coal. A shaft should be sunk further from the superficial outcrop than the present pits. In order to

reach the diamantiferous conglomerate, the depth of such a shaft at the foot of the Rewa scarp would have to be about 200 to 250 feet. About half-way between the foot of the scarp and the limit of the outcrop, the depth would be about half that amount, that is, about 100 feet. It might be advisable to commence work with a shaft of about that depth in order to minimise the initial expenditure. The shaft would then constitute the deepest portion of the mine, and the work would proceed by galleries driven up the dip-slope. By this method, parts of the field could be attacked that have never before been touched. The drainage of the mine would be pumped from its lowest level, that is, from the shaft.

It is difficult to estimate the cost of working by this method because this diamantiferous conglomerate is very different from all other diamantiferous deposits in other parts of the world, so that the workings in other places, such as South Africa or Brazil, can furnish no point of comparison. The only form of mining that resembles the one I propose, is coal-mining. I have attempted to form an idea of the probable cost by considering that of mining in the Bengal coal-fields. I am indebted, for the following figures, to the kindness of my colleague, Mr. Simpson, Mining Specialist, Geological Survey of India:—

Cost of well-regulated colliery in Raniganj coal-field, Bengal (by E. S. Wood, Esq., Bengal Coal Co.).

	Cost per ton.		
	R	a.	p.
Coal-getting	0	14	6
Under-ground labour	0	3	0
Surface labour	0	2	6
Stores	0	3	6
Workshops	0	2	0
Repairs	0	1	6
	1	14	6
Calcutta Agents	0	6	0
	2	4	6

In order to compare this cost with the probable cost of extracting the diamond ore by systematic mining, it is useful to find out the cost

per cubic foot instead of per ton. The item "Calcutta Agents" can be neglected, as it would not occur in the proposed diamond mining, so that it is sufficient to regard R1-14-6 as the cost per ton, making the cost per cubic foot R1-2-3 on the supposition that the density of the coal is 1·4.

The extraction of a cubic foot of the diamantiferous conglomerate will cost much more than the above figure, first, because the rock is so much harder than coal, and, secondly, because, as its thickness seldom exceeds one foot, it is necessary to excavate a certain amount of unproductive material in order that the galleries be 3 or 4 feet high, sufficient for the men to work. Therefore, to uncover and extract an amount of conglomerate occupying one square foot in plan, it will be necessary to remove a column of strata of about 4 cubic feet in bulk, of which 3 feet or more may consist of shale, the remainder of conglomerate. If the cost per cubic foot were the same as for coal, the work would cost about 4 annas 9·2 pies per square foot of conglomerate, regardless of its thickness. The shales are very easily removed and the cost of excavating them is probably not greater than in the case of coal. But the cost of removing the conglomerate, and that of the surface operations, is greater in the case of diamond ore than in the case of coal.

It will not be possible to use in an under-ground mine the present method of heating the surface of the stone to detach the conglomerate, which must be either blasted or wedged, whichever proves to be more convenient and economical. This is a cost which does not occur in Indian coal-mining, and it is difficult to reckon how much must be added per superficial square foot on that account. At the same time, there should be a slight difference in favour of the diamond mines in that the excavated shale need not be raised out of the mine, as it is of no value and can be used for filling up the worked-out galleries.

In the neighbourhood of Itwa, where shales underlie the conglomerate which is therefore situated at the roof of the galleries, wedging would be easy and inexpensive.

It will probably be safe to assume that the above figure should be doubled, raising the total cost per square foot of conglomerate to 9½ or 10 annas.

It remains now to find out whether more than nine or ten annas worth of gems can be expected on the average from every *square* foot of conglomerate. The following figures kindly communicated by

the Panna Darbar represent the total output for a period of one year, of the "direct" workings at Sháhidan :—

Statement showing the total outturn of the group of Sháhidan mines for the year 1904.

Serial No.	Months.	No. of Diamonds.	Weight. Ratis.	Weight. Biswas.	Price. R	a.	p.
1	January	9	13	1	682	8	0
2	February	15	16	15	959	8	0
3	March	16	28	8	1,448	6	6
4	April	10	13	3	659	3	3
5	May	12	11	10	459	6	6
6	June	14	19	16	982	10	9
7	July	24	24	8	919	6	9
8	August	35	41	11	1,437	2	9
9	September	29	33	3	1,303	5	3
10	October	13	12	0	547	6	6
11	November	10	6	8	183	3	6
12	December	9	8	10	371	8	9
	TOTAL	196	228	16	9,952	12	6
	Diamonds weighing 6 Ratis and above.						
1	February	1	31	8	4,396	0	0
2	April	1	6	18	207	0	0
3	September	1	8	6	1,079	0	0
	TOTAL	3	46	12	5,682	0	0
	GRAND TOTAL	**199**	**275**	**8**	**15,634**	**12**	**6**

During the period which this list refers to, the average number of the Sháhidan mines was about 20. From the dimensions of the shafts, and the area occupied by the radiating tunnels, I am probably not far wrong in assuming that the average area uncovered in each of these mines is about 40′ × 40′, that is, 1,600 square feet. Distributing over that area the total value of the diamonds raised, it would give an average of 8 annas per square foot, which could not pay according to the above calculation. Possibly, however, my data are not sufficiently accurate. It is difficult, nevertheless, to detect the flaw in this estimate, for in considering the case of Lalla Ram Sukh's mine, regarding which I have obtained accurate information, I find that the

cost of mining, according to the present method, is at least 9 annas per square foot. According to the current regulations the State's share is one quarter of the value of gems below 6 ratis in weight. Therefore, the expenses could not be covered unless the average value of the gems were 12 annas per square foot, and in order to give anything like a margin of profit, it would have to be much greater still, probably R1.

Lalla Ram Sukh's mine has been described in a previous section of this chapter (pages 290-1). Its diameter is 35 feet, and, taking into account the galleries driven round it, the total area of conglomerate uncovered cannot be less than 1,600 square feet.

The expenses gathered from the above-quoted figures would be about as follows:—

	R
Ten men at R6 for 2½ months	150
Fifteen women at R3 for 2½ months	112·5
Eight men at R6 for 9 months	432
Eight women at R3 for 9 months	216
Cost of tools	30
	940·5

This gives a cost of more than 9 annas per square foot. I neglected to ascertain the cost of the wood used as fuel for breaking up the conglomerate. It amounts probably to R8 or R10. With sundry other unforeseen expenses, the cost may be reckoned at something between 9 and 10 annas per square foot.

Applying this information to that contained in the previous list, there are some more points deserving careful attention. Deducting the proportion allotted to the State, that is, one-fourth of the value with regard to diamonds of less than 6 ratis, and three-fourths with regard to those of that weight and above, we find that the value obtained by the miners was R8,884-8. On the other hand, if there were 20 mines worked at an average cost of R500, this would imply a total expenditure of R10,000, leaving the miners the losers by over R1,000. The average of R500 which was stated to me must be about correct, for, in the cost given for Lalla Ram Sukh's mine, the expenditure under the head of surface operations alone comes to nearly R300 and must recur practically to the same amount in every other mine. The only item subject to any great variation is that regarding the actual excavation. In this one particular instance it amounts to R652½. In some of the mines it must be much less, but in many others it must be much

more, either on account of the greater depth of the pit, or owing to the necessary installation of a "persian wheel." Therefore the average of R500 cannot be at all over-estimated. This being so, it follows that, if I have not been completely misinformed regarding the number and importance of the mines, the figures, as they stand, imply working at a considerable loss. Whatever may be the chances of an occasional big find and their influence in encouraging a gambling spirit amongst the workers, it seems incredible that a whole community should deliberately continue, year after year, to work this area at such a serious loss. Unless, therefore, some of my data are quite incorrect, it must necessarily follow that some of the gems are diverted, and that the persons responsible for these abstractions are not the actual labourers, but their employers. This conclusion is a matter of importance in connection with any scheme for working on a more extensive scale, showing, as it does, that it is not the actual labourers who are most to be feared in this respect. Moreover, as will be easily understood from the details given in the previous chapter dealing with the extraction of the gems, there is not much opportunity of finding any gems during the actual work of excavation, as they mostly turn up during the subsequent operations.

So far as can be estimated from a consideration of these data, we may regard 12 annas as the minimum value of the superficial square foot of the diamond conglomerate. On an average, the present cost of working appears to be about the same, per square foot, as what I have regarded as a probable estimate for systematic mining. Only it must be kept in mind that, in the latter case, the cost will not be greater at 300 feet depth than at 30, and, therefore, it will be possible to open out an area out of all proportion with the small field accessible by the present method.

If a shaft is sunk at the foot of the "Rewa" scarp, it will have to be about 250 feet deep in order to reach the diamantiferous conglomerate. In order to restrict initial expenditure, there is, however, no reason to start with such a deep shaft. As I have already remarked, a point can be selected where the depth will not be more than 100 feet. At any point situated half-way between the Upper Rewa scarp and the northern boundary of the Lower Rewa shales, or limestones, the conglomerate may be expected at about that depth.

Beyond the Rewa scarp, that is, on the Upper Rewa dip-slope, a shaft, in order to reach this conglomerate, would have to traverse the whole thickness of the Rewa sandstone, which would add enormously

to the cost. The area that can be profitably worked is, therefore, practically coincident with the outcrop of the Rewa shales. The conglomerate is known to occur as far as Bambia on the eastern side and Kishengarh to the west, a length of about 65 miles. It is not certain, however, that it is diamantiferous for the whole of that extent. But it may be fairly assumed that it is so throughout the area included between the easternmost and westernmost diamond mines, that is, from Majgama in Paterkechar territory, east of the valley of the Bagain, up to another locality also called Majgama in Panna territory, 12 miles south-west of Panna. Between these limits the area under which the diamantiferous layer could be reached by shafts of less than 250 feet is over a hundred square miles, and this estimate must be nearly doubled if the layer maintains a sufficient proportion of gems up to Kishengarh and Bambia.

The matter is so clear that there seems no reason why the work should not be undertaken by the State. Further prospecting cannot disclose anything new. The only preliminary work to be undertaken is that of making a few excavations. If these yield satisfactory results, a moderate capital should suffice to start systematic work. After careful consideration, I am of opinion that it is essential, for the success of the enterprise, to secure from the very commencement, and for a certain number of years at least, the services of a fully qualified and experienced European mining engineer, one with a knowledge of coal-mining, which is the only sort of mining that can be compared to the present one. A competent engineer of this kind might be obtained at a salary of R1,000 a month. In the Bengal coal-fields the cost of sinking a shaft is about R40 per foot for depths between 100 and 500 feet. One year, or, at most, two years, of systematic trials should be amply sufficient to settle the possibility of remunerative working.

Various improvements in the surface operations, such as the use of mechanical crushers, or of mechanical appliances for sorting the material according to specific gravity, would, no doubt, readily suggest themselves to a competent engineer. The surface operations could, no doubt, be improved and systematised so as to necessitate far less handling than is at present needed. I have already mentioned that in the actual extraction of the conglomerate the chances of finding gems are very small. It is therefore the surface operations that more particularly need strict supervision, though the employment of women and children entirely precludes the possibility of such severe measures as are practised in the South African mines. The women and

children are often more skilful than the men in picking out the stones, and I believe it is a well-recognised principle in the employment of Indian labour to attempt to combine the work of men and women and children, thus enabling all the members of one family to assist one another in gaining their livelihood. Systematising the work will allow better supervision and will minimise the chances of peculation. A certain amount of loss is inevitable in an enterprise of this sort, but in countries like India coercive measures like those of South Africa cannot be resorted to, and it is only by infinite patience and tact that this difficulty can be dealt with. There should be a better chance of ultimately obtaining this result if the State are the employers than if the workings are leased to an outsider.

Until something is decided regarding the systematic development of the ore, it would be most inadvisable to interrupt any of the workings at present in progress. They should be restricted, however, to the area which is worked at present, and no fresh area should be opened out. But it is essential to keep the work going so as to preserve a nucleus of skilled workers. A plan of the works in their present state should be surveyed and kept up to date every following season, so as to avoid working the same areas twice over.

Regarding the "shallow" workings, it is most important that at places like Bhowanipur, that are actively worked, some method should be immediately imposed upon the workers, to avoid the enormous amount of waste that must otherwise ensue.

The area which is at present worked has been treated so irregularly that there is probably not much chance of improving it. But immediately south of the portion riddled by shallow pits, no further work should on any account be permitted, unless it conforms to a systematic plan.

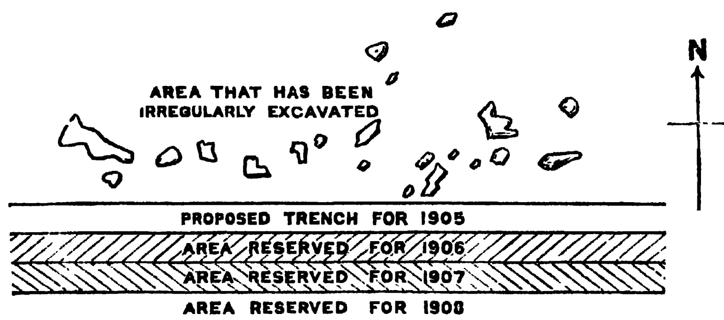


FIG. 7—*Plan of portion of proposed systematic working at Bhowanipur.*

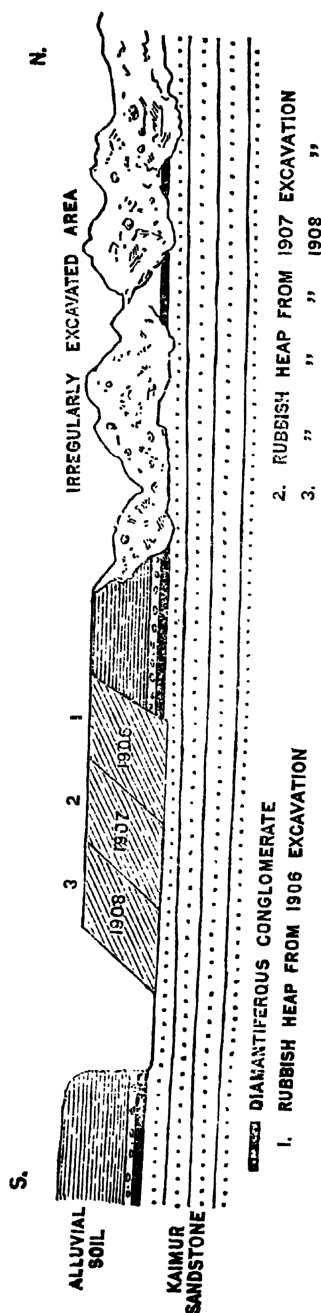


FIG. 8—*Section of proposed working as it should appear in 1909.*

I would suggest that, south of the area that has been irregularly burrowed, a regular trench, of convenient width, say, 10 to 20 feet, should be excavated, and the material carted away. The miners themselves can dig this trench, as they will thereby uncover the diamantiferous layer, but it might be advisable to cart away the rubbish at the expense of the State, as this will not recur in following years. Once this has been done, no further work should be allowed, except along a strip of land parallel with the open trench. This open trench will constitute a convenient dumping ground for the rubbish from the excavations in progress. In this way a clear face will always remain, and the work can continue, year after year, in a southerly direction by the removal of successive slices, until the depth becomes so great that underground mining would be more remunerative (see diagrams Figs. 7 and 8).

The searching floors and washing troughs might be congregated round certain definite spots, which might make them more permanent and might be a convenience to the workers, while facilitating supervision. I would suggest to sift the material with wire screens, as it seems to me that it would facilitate searching for gems if the particles were more uniform in size.

With regard to the alluvial workings, it is scarcely possible to suggest much improvement on account of the inevitable irregularity of their mode of occurrence. They should, however, be surveyed like the other workings, as, in this case too, there is always a danger of useless and unprofitable expenditure from attempting to works the same area twice over as the sites of old pits get forgotten.

PART II.—MINERAL RESOURCES OTHER THAN DIAMONDS.

I.—Building stones.

The State of Panna contains a considerable exposure of the Kaimur sandstone which yields building stones of superior excellence wherever it occurs in India. It is divisible into two groups, a lower one consisting of thick-bedded sandstones often of great hardness, and an upper one of thinner-bedded strata. It is this upper one which is the most useful, for it contains beds so flaggy that they can be used as slabs, and others of greater thickness up to 3 or 4 feet. The grain is even, the material compact, and yet not so hard as to be difficult to work. The colour of this rock is white or very pale yellow, sometimes faintly streaked with pink. In the lower thick-bedded subdivision the colour is of a pale buff and often very uniform. In other parts of India the Kaimur sandstone is seldom so colourless as in Bundelkhand. The reason is probably that in Bundelkhand it has been derived mainly from the disintegration of the Bundelkhand granite, a rock which yields a very pure siliceous sand, almost entirely free from ferruginous matter. In other parts of India the Kaimur sandstone has often been derived from rocks that are more ferruginous than the Bundelkhand Gneiss, and, as a consequence, their colour is often of various shades of red.

In addition to numerous modern buildings, the Kaimur sandstone of Bundelkhand furnished the materials of which are built those gems of mediæval art, the famous temples of Kajraha. The most beautiful of all the larger temples, the one nearest the tank and called sometimes temple of Chatur Bhuj, and sometimes temple of Lachman, appears to have been built entirely with the hard sandstone of the lower subdivision. The ancient quarries from which it was obtained appear to have been situated at the outlying hill of "Jhanna" (Pl. 24). It is probably the extreme hardness of this stone that accounts for the wonderful state of preservation of its exquisite carvings, although this temple is not far from 1,000 years old. The next large temple to the north of this one is only slightly less elaborate, and seems also to have been all built of choice material. In both these temples, the material is of uniform quality and colour. In the other temples this better quality of sandstone has been used only for the more choice carvings. For the plain parts of the work, and for pillars, cornices, friezes, running ornaments, the thinner-bedded varieties either overlying or underlying the thicker-bedded ones have been largely drawn upon. Hence many of the ornaments are not nearly so beautifully preserved as in the two

temples first mentioned. Many of the blocks are conglomeratic. Blocks of different colours, white, yellow or striped with red, were originally placed in irregular juxtaposition. But all the parts most exposed to the rain have become black, while the vertical portions and those better protected have taken with age a uniformly golden tint which makes them appear quite similar in general appearance to the material of the two temples first mentioned. I mention these particulars because the distinguished archæologists who have lately examined these temples appear to have been under the impression that they were all uniformly built with this yellow sandstone, and decided that in some restorations which it is proposed to undertake only a coloured sandstone should be used that would match the present appearance of the temples. The Panna Darbar have been much exercised in attempting to find a suitable material. Beds approaching the requisite colour are seldom met with, and then only in patches, or of less than the requisite thickness, or too hard, or otherwise unsuitable. It should therefore be mentioned that no extensive mass of sandstone could be found recalling the beautiful golden tint now exhibited by the temples. This is only a superficial patina which the stone has acquired with age: the original colour of the stone disclosed by removing this film is invariably much paler.

2.—Iron.

The iron ores are of two kinds: the lateritic ones consisting of hæmatitic nodules scattered through the lower clayey portion of certain kinds of laterite, and the ore occurring in connection with the Bijáwar strata which is a ferruginous breccia. They have been described by Medlicott in the Memoir already referred to, and by Ball in the Economic Manual of the Geology of India. They are still smelted to a small extent in charcoal furnaces, but I doubt whether the iron industry can ever be revived in India by smelting according to the native methods, simply because iron is a material now produced on such an enormous scale that the very narrowest possible margin of profit has been reached, and its production is remunerative only where there is an exceptional combination of favourable circumstances and when the work is carried out on an enormous scale. To try to smelt iron on a small scale at the present day is probably equivalent, from an economic point of view, to attempting to prepare galvanised or corrugated iron, or lead pipes, or soda-water bottles on a small scale and by manual labour. The result would be so imperfect, and the profit so small, that not even he low-wage-earning population of India could live by it

3.—Lime.

In addition to the calcareous tufa of the river-gorges which is, to some extent, worked for lime at the present day, the Bhander limestone which outcrops all along the "Haveli" valley contains inexhaustible stores of material identical with that exploited in Rewa by the Sutna Lime Company.

4.—Laterite.

Allusion has already been made to the ferruginous laterite largely developed in the State, which constitutes an excellent material for road-making. Some of the ochreous clays associated with it are used as pigment.

G. I. C. P. O.—No. 5 D G. Survey—30-6-06.

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